third fractures, neutral for middle third and pronation for distal third.

- Follow-up X-rays should be taken at 1- and 2-week intervals following manipulation to ensure that secondary displacement has not occurred. If displacement does occur, re-manipulation can be attempted.

- Some very unstable fractures may prove difficult to treat by closed methods. These may benefit from intramedullary pinning (Rush pins) or cross K-wiring if facilities exist for this (intra-operative fluoroscopy is required).

**Distal radial (‘wrist’) fractures**

- Children’s distal radial fractures are usually the result of a fall on the outstretched hand, and are rarely intra-articular.

- Common types include the following:
  - Galeazzi fracture (isolated fracture of the distal radius) implies associated disruption of the distal radio-ulnar joint.
  - Physeal fracture (pattern of injury described by the Salter-Harris classification)
  - Torus (buckling of the cortex on the compression side of the fracture without angulation).
  - Greenstick fracture (incomplete fracture).

- In children these fractures can almost always be treated with closed reduction and plaster immobilisation.

- The reduction manoeuvre is to hyperextend the wrist, followed by traction and ‘hinging’ of the distal fragment over the fracture site.

- Acceptable reduction can be defined as anything less than complete displacement and slight angulation. As in forearm fractures, cosmetic deformity should remodel if more than 2 years of skeletal growth remain.

- Check X-rays should be taken at 1 and 2 weeks post-reduction to exclude secondary displacement.

- The duration of immobilisation required depends upon the fracture configuration and the age of the child, but is typically 3–5 weeks.

**Conclusions**

- Most paediatric fractures can be treated by closed methods.

- Very often the periosteal sleeve will be intact, leading to enhanced fracture stability.

- Completely accurate reduction is not always necessary, as children’s bones have the potential to remodel with continued skeletal growth.

### 7.3.A Structured approach to trauma in pregnancy and childhood

**BOX 7.3.A.1 Minimum standards**

- Triage.
- Structured approach: primary assessment and resuscitation, and then secondary assessment and emergency treatment.
- Availability of emergency surgery or safe transport system.
- Oxygen.
- Blood transfusion service.
- Chest drain.
- Analgesia.
- High-dependency care.
- Tetanus immunoglobulin and toxoid.
- Mannitol or hypertonic saline.
- Tranexamic acid.

**Introduction**

Most regions of the world are experiencing an epidemic of trauma, but the most serious increase has been in the resource-limited countries.

Proliferation of roads and increased use of vehicles have led to an increase in injuries and deaths, and many peripheral medical facilities find themselves faced with multiple casualties from bus crashes or other disasters. Severe burns and drownings have always been more common in middle- and low-income countries.

There are a number of important differences between high- and low-income countries:

- use of open fires and kerosene stoves for cooking and heating
- unsafe water storage practices and unsupervised play in water courses, lakes and ponds by young children
- poor or absent flood defences, making poor people much more vulnerable to natural disasters
- poorly maintained road networks and vehicles, contributing to a higher injury rate per distance travelled in low-income countries
- the absence of a paramedic-manned emergency ambulance service to give life-saving medical care at the scene
- the great distances over which the injured may have to be transported, and therefore the time taken for them to reach medical care, thus losing the opportunity to prevent secondary damage caused by hypoxia and hypovolaemia
- the absence of appropriate equipment, supplies, and the
necessary knowledge and skills to manage the injured once they have arrived at a healthcare facility.

- the absence of skilled people to operate and service equipment.

Prevention of trauma is by far the best and most cost-effective way forward, but accident prevention has not yet had much impact in low-income countries.

Trauma is the commonest cause of death in children over the age of 5 years in high-income countries, and it is increasing in absolute numbers as well as in ranking in low- and middle-income countries. In the World Health Organization (WHO) 2008 report ‘World Report on Child Injury Prevention’, the death rate in under 20 year olds from injury was 12.2 per 100,000 in high income countries while in low and middle income countries, the figure was 41.7 per 100,000.

Trauma is also a major cause of disability, especially following head injury, burns and drownings. In high-income countries, road accidents and falls predominate; in low-income countries road traffic accidents are increasing, but there has been no fall in the number of burns, falls and drownings.

Children are less likely than adults to suffer from serious penetrating injuries, although in cities where stabbings and shootings are common, or in armed conflict, such violence spills over into childhood. Intentional injury, in the form of child abuse, also contributes to a significant degree to childhood trauma (see Section 7.6).

The patterns of injury and the physiological consequences can be quite different in children compared with adults, reflecting their different size and shape, the elasticity of their body tissues, and the immaturity of their physiological systems.

The key principles of managing major trauma are to:

- Treat the greatest threat to life first
- Do no further harm
- AVoID: hypoxia, hypercapnia, hypovolaemia, hypoglycaemia and hypothermia

By following a structured approach, problems will be identified and managed in order of priority. The key steps are outlined in the primary assessment and resuscitation, enabling identification and treatment of life-threatening injuries. The secondary assessment identifies all other injuries, and provides emergency treatment for them.

Management of major trauma

A team leader should be in overall charge of resuscitating a child or pregnant woman or girl who is suffering from major trauma.

Primary assessment and resuscitation

During the primary assessment, assess and resuscitate in sequence – Airway, Breathing and Circulation (ABC) – as these, if compromised, can be an immediate threat to life.

Although the patient may have obvious severe injuries, the clinician’s first task is to prevent further deterioration of the patient’s condition by ensuring that vital organs, especially the heart and the brain, are supplied with oxygenated blood by ensuring an open airway, adequate breathing and circulation. This is what is meant by primary assessment and resuscitation.

Although ABC management is described sequentially, if there are sufficient trained clinicians present, they can be managed at the same time. If there are limited personnel, the approach must be A then B then C. If there is only one trained person available, make use of untrained staff such as ward orderlies or relatives to perform tasks under your supervision. For example, if there is visible severe exsanguinating haemorrhage, once you have identified and controlled it, the ward orderly can continue to apply the pressure while you open the airway and give oxygen, etc. You will need to continually monitor the untrained person’s actions to make sure that they are still effective.

The first priority is establishment or maintenance of airway opening, and control of any obvious life-threatening haemorrhage.

Primary Assessment and Resuscitation:

Airway and control of exsanguinating haemorrhage (plus cervical spine control, if appropriate)

Breathing

Circulation

Stop visible external exsanguinating bleeding. If any, by applying direct pressure. This bleeding will be from a superficial artery or large vein. Minor bleeding can be left until the vital ABC have been assessed and resuscitated. Internal bleeding will be dealt with first in ‘C’ by replacing fluid, and then, if necessary, by emergency surgery.

Open and maintain the airway

We assess the airway patency by assessing its function, which is to allow air to pass through it into the lungs. If the airway is blocked, the lungs will not receive air.

The approach is similar to that used for managing any airway, in that you must:

- Look for chest movement
- Listen for breath sounds
- Feel for exhaled air
- Talk to the patient

Structured approach

Primary assessment and resuscitation

Secondary assessment and emergency treatment

Definitive care

Primary assessment

- Airway and control of haemorrhage (and cervical spine control)
- Breathing
- Circulation and continued haemorrhage control

If there is more than one injured patient, then treat the patients in order of priority (see Section 1.10).
If the patient is conscious, a rapid way to assess the airway is to ask them to speak, using the question ‘Are you all right?’

A patient who can speak (or, in the case of a baby, who can cry) must have a clear airway.

If the patient is unconscious, airway obstruction is most commonly due to obstruction by the tongue.

The signs of airway obstruction may include:
- snoring or gurgling
- stridor or abnormal breath sounds
- agitation (hypoxia)
- using the accessory muscles of ventilation/paradoxic chest movements
- cyanosis.

**Cervical spine protection**

In countries where there is no trained emergency ambulance service available to rescue trauma victims at the scene, the risk of an unstable cervical fracture causing permanent spinal cord damage, and subsequent paresis occurring before the patient is brought to medical attention, is high. Therefore any cervical fracture presenting to the scene, the risk of an unstable cervical fracture causing permanent spinal cord damage, and subsequent paresis occurring before the patient is brought to medical attention, is high. Therefore any cervical fracture presenting to a medical facility after being brought in by passers-by is likely to be stable.

Fortunately, unstable cervical spinal fractures are relatively uncommon. They are more likely to occur as a result of very severe road traffic accidents or falls from a significant height.

**Protect the cervical spine with collar, sand bags and tape if the patient is likely to have an unstable cervical spine.**

Definitive treatment requires specialist surgery, and health services in many low-income countries may struggle to access the appropriate service for their population.

It is important to recognise that although protection of the cervical spine may occasionally be beneficial, the opening and maintaining of a clear airway benefits every patient and is an absolute priority.

**Cervical spine immobilisation**

The cervical spine can be mobilised in three ways:
1. **In-line stabilisation:** the spine is held in the neutral position (the same as the airway position for an infant; see Section 1.12) by the clinician’s hands on either side of the patient’s head, ensuring that the ears are not covered, as the patient must be able to hear to be reassured and informed. This position must be held until the collar and/or blocks are in place.

2. A cervical collar can be placed around the neck. Before placing the collar, gently feel around the back of the patient’s neck to ascertain if there is any midline tenderness and/or a ‘step’ indicating a fracture or if there is any bleeding. Collars are manufactured in several sizes to fit different sized patients. They are measured according to the manufacturer’s instructions and then gently slid under the neck at the back. The shaped part is placed under the chin at the front, and the collar is fastened with the ‘Velcro’ tape fastening. This should leave the patient with a firmly held neck in a neutral position. The collar is used by itself in the combative patient, and in conjunction with blocks or sandbags in the unconscious or cooperative patient (i.e. one who will remain still).

3. Sandbags or blocks and tape are usually added after the collar has been fitted. They cannot be used in combative patients as their movements to free themselves will cause more injury. They are essential in the unconscious patient who has a possibility of neck injury. These objects are placed on either side of the patient’s head to prevent lateral movement, and held in place with two tapes, one across the patient’s forehead and the other across the chin part of the cervical collar.

**Management of the airway**

- **Head tilt/chin lift or jaw thrust.** Jaw thrust is recommended in trauma, as it does not require any neck movement. However, if a jaw thrust is unsuccessful, try chin lift with some head tilt. A closed airway will always be potentially fatal, so the airway takes priority.
- **Suction/removal of blood, vomit or a foreign body.** If any, but only under direct vision. Do not blindly suck in the mouth or pharynx.
- **If there is no improvement, place an oropharyngeal airway.** Avoid using a nasopharyngeal airway if base of skull injury is suspected.
- **If the airway is still obstructed, a definitive airway by intubation or surgical airway may be needed.**

Identify the ‘at-risk’ airway:
- Altered level of consciousness will fail to protect the airway.
- Vomiting, with risk of aspiration, is a major risk in pregnancy.
- Facial trauma, including burns, will continue to worsen as the tissues swell.

Once the airway is open, give high-flow oxygen using a mask and reservoir.

If the airway cannot be maintained and/or protected, consider the need for advanced airway management.

Indications for advanced techniques for securing the airway (intubation or surgical airway) include:
- persistent airway obstruction
- a conscious level of ≤ 8 on the Glasgow Coma Scale, or ‘P’ or ‘U’ on the AVPU scale (see below for both)
- penetrating neck trauma with haematoma (expanding)
- apnoea
- hypoxia
- severe head injury
- chest trauma
- maxillofacial injury.

Intubation techniques should ideally be performed by an experienced anaesthetist. A surgical airway is best performed by an ENT surgeon, but general surgeons will have been trained even if they are not experienced in the technique. The technique of emergency cricothyrotomy can be performed by any emergency clinician (see below).

For intubation, the following sequence should be followed:
1. Pre-oxygenation with 100% oxygen, with manual lung inflation if required.
2. Administration of a carefully judged, reduced dose of an anaesthetic induction agent.
3. Application of cricoid pressure.
4. Suxamethonium 1–2 mg/kg.
5. Intubation with a correctly sized tracheal tube.
Confirmation of correct placement of the endotracheal tube

Signs such as chest movement and auscultation remain helpful, but are occasionally misleading, especially in inexperienced hands. The most reliable evidence is to see the tube pass through the vocal cords. The correct size is a tube that can be placed easily through the cords with only a small leak. Intubation of the right main bronchus is best avoided by carefully placing the tube only 2–3 cm below the cords, and noting the length at the teeth before checking by auscultation, which is best done in the left and right lower axillae. Capnography (if available) is a useful adjunct to help to confirm correct tube placement.

Indications for surgical cricothyrotomy

- Inability to open or clear the airway, and the patient losing consciousness due to cerebral hypoxia (usually also cyanosed and bradycardic).
- Inability to ventilate the lungs despite high-level CPAP via a bag-valve-mask system and 100% oxygen through a reservoir attached to the bag.
- Inability to intubate through the larynx, either because this is not possible or due to lack of experience.

Method

1. Place the patient in a supine position.
2. If there is no risk of neck injury, consider extending the neck to improve access. Otherwise, maintain a neutral alignment.
3. Identify the cricothyroid membrane (see Figure 7.3.A.1).
4. Prepare the skin, and, if the patient is conscious, infiltrate with local anaesthetic.
5. Place a hand on the neck to stabilise the cricothyroid membrane, and to protect the lateral vascular structures from injury.
6. Make a small vertical incision in the skin, and press the lateral edges of the incision outwards, to minimise bleeding.
7. Make a transverse incision through the cricothyroid membrane, being careful not to damage the cricoid cartilage.
8. Insert a tracheal spreader, or use the handle of the scalpel by inserting it through the incision and twisting it through 90 degrees to open the airway.
9. Insert an appropriately sized endotracheal or tracheostomy tube.
10. Ventilate the patient and check that this is effective.
11. Secure the tube to prevent dislodgement.

Complications of surgical cricothyroidotomy

These include the following:

- asphyxia
- aspiration (e.g. blood)
- laceration of the trachea
- laceration of the oesophagus
- haemorrhage or haematoma formation
- mediastinal emphysema
- subsequent glottic stenosis
- creation of a false passage into the tissues
- subsequent subglottic stenosis or oedema.

Primary assessment and resuscitation: Breathing

After management of the airway, the patient’s breathing should be assessed. The same approach is adopted as for the patient suffering a serious illness.

Assessment of breathing

- Effort: recession, rate, added noises, accessory muscles, alar flaring.
- Efficacy: breath sounds, chest expansion, abdominal excursion.
- Adequacy: heart rate, skin colour (look for cyanosis), mental status.
- A pulse oximeter is very useful to monitor oxygenation adequacy (SaO2).

Unequal breath sounds or poor oxygenation:

- Pneumothorax or haemothorax.
- Misplaced or blocked endotracheal tube.

Looking at the respiratory rate and chest expansion is essential. In addition to the signs listed above, check whether any of the following are present:

- penetrating injury
- presence of flail chest
- sucking chest wounds.

Listen for breath sound character and equality:

- pneumothorax (decreased breath sounds on site of injury)
- detection of abnormal sounds in the chest.

Feel for:

- tracheal shift (sign of tension pneumothorax on side away from the deviation)
- broken ribs
- subcutaneous emphysema.

Percuss:

- percussion is useful for diagnosis of haemothorax (dull on affected side) and pneumothorax (hyper-resonant on affected side).

Continue giving high-flow oxygen (15 litres/minute) in all cases.

Careful examination of the trachea, neck veins and chest may indicate the presence of pleural collections of air or blood. Tension pneumothorax should be treated immediately with needle thoracocentesis in the second intercostal space in the mid-clavicular line.
**Needle thoracocentesis**

This procedure is used for the rapidly deteriorating patient who has a life-threatening tension pneumothorax. If it is used with a patient who does not have a tension pneumothorax, there is a 10–20% risk of producing a pneumothorax or causing damage to the lung, or both. In such cases immediate subsequent insertion of a chest drain is mandatory.

1. Identify the second intercostal space in the mid-clavicular line on the side of the pneumothorax (the opposite side to the direction of tracheal deviation, and the same side as the hyper-resonance).
2. Swab the chest wall with surgical prep or an alcohol swab.
3. Attach the syringe to the over-needle venous cannula.
4. Insert the cannula into the chest wall, just above the rib below, aspirating all the time.
5. If air is aspirated, remove the needle, leaving the plastic cannula in place. Alternatively, insert the over-needle venous cannula without a syringe and note a ‘hiss’ of air on relief of the tension pneumothorax when the metal stylet is removed from the plastic cannula.
6. Tape the open cannula in place and proceed to chest drain insertion as soon as possible.

**Complications of needle thoracocentesis**

- Local cellulitis.
- Local haematoma.
- Pleural infection.
- Empyema.
- Pneumothorax.

**Ventilation**

Provide assisted ventilation if needed to patients with breathing problems, using a bag and mask with a reservoir attached, or by intubation and intermittent positive pressure ventilation. Do not persist with intubation attempts without oxygenating the patient.

**Look for and treat the following:**

- Airway obstruction (see above)
- Tension pneumothorax
- Open pneumothorax
- Haemothorax
- Flail chest
- Cardiac tamponade.

See below for details.

**TABLE 7.3.A.1 Serious chest trauma: signs and treatment**

<table>
<thead>
<tr>
<th>Breathing problem</th>
<th>Clinical signs</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tension pneumothorax</td>
<td>Decreased air entry on one side of pneumothorax</td>
<td>High-flow oxygen</td>
</tr>
<tr>
<td></td>
<td>Decreased chest movement on side of pneumothorax</td>
<td>Needle thoracocentesis</td>
</tr>
<tr>
<td></td>
<td>Hyper-resonance to percussion on side of pneumothorax</td>
<td>Chest drain insertion</td>
</tr>
<tr>
<td></td>
<td>Tracheal deviation away from side of pneumothorax</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hypoxic shocked patient</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Full neck veins</td>
<td></td>
</tr>
<tr>
<td>Open pneumothorax</td>
<td>Penetrating chest wound with signs of pneumothorax</td>
<td>High-flow oxygen</td>
</tr>
<tr>
<td></td>
<td>Sucking or blowing chest wound</td>
<td>Chest drain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wound occlusion on three sides</td>
</tr>
<tr>
<td>Massive haemothorax: blood in pleural space</td>
<td>Decreased chest movement</td>
<td>High-flow oxygen</td>
</tr>
<tr>
<td></td>
<td>Decreased air entry</td>
<td>Venous access and IV volume replacement</td>
</tr>
<tr>
<td></td>
<td>Dullness to percussion</td>
<td>Chest drain (a haemothorax of 500–1500 mL that stops bleeding after insertion of an intercostal catheter can generally be treated by closed drainage alone; a haemothorax of greater than 1500–2000 mL, or with continued bleeding of more than 200–300 mL/hour, may be an indication for further investigation, such as thoracotomy)</td>
</tr>
<tr>
<td></td>
<td>Shock and hypoxia</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Collapsed neck veins</td>
<td></td>
</tr>
<tr>
<td>Flail chest: paradoxical movement of a chest wall</td>
<td>Rare in children because they have an elastic chest wall</td>
<td>Oxygen and pain relief</td>
</tr>
<tr>
<td>segment associated with underlying lung contusion</td>
<td>Decreased efficiency of breathing</td>
<td>May need intubation and ventilation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transfer if feasible</td>
</tr>
<tr>
<td>Cardiac tamponade: blood in pericardial sac causing a</td>
<td>Shock associated with penetrating or blunt chest trauma</td>
<td>Oxygen</td>
</tr>
<tr>
<td>decrease in cardiac output</td>
<td>Faint apex beat and/or muffled heart sounds</td>
<td>IV access and IV fluids</td>
</tr>
<tr>
<td></td>
<td>Distended neck veins</td>
<td>Emergency needle pericardiocentesis (see Section 8.4.C: may need to be repeated)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Consider transfer if feasible</td>
</tr>
</tbody>
</table>

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Primary assessment and resuscitation: Circulation
Assessment of circulation
Circulatory assessment includes identification of actual and potential sources of blood loss. Closed fractures and bleeding into the chest, abdomen or pelvis may make it difficult to detect how much blood has been lost. The ability to estimate the percentage blood loss is helpful when planning resuscitation. Remember that a child’s circulating blood volume is only 80 mL/kg, so is easily compromised. Blood volume in pregnancy is 100 mL/kg, or 5–7 litres.

<table>
<thead>
<tr>
<th>TABLE 7.3.A.2 Blood loss in pregnancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage blood loss</td>
</tr>
<tr>
<td>Sign</td>
</tr>
<tr>
<td>Heart rate</td>
</tr>
<tr>
<td>slight increase</td>
</tr>
<tr>
<td>moderate increase</td>
</tr>
<tr>
<td>marked increase or bradycardia</td>
</tr>
<tr>
<td>Systolic BP</td>
</tr>
<tr>
<td>normal</td>
</tr>
<tr>
<td>normal</td>
</tr>
<tr>
<td>beginning to fall</td>
</tr>
<tr>
<td>Pulse volume</td>
</tr>
<tr>
<td>normal or decreased</td>
</tr>
<tr>
<td>seriously decreased</td>
</tr>
<tr>
<td>very seriously decreased</td>
</tr>
<tr>
<td>Skin*</td>
</tr>
<tr>
<td>cool, pale, sweaty</td>
</tr>
<tr>
<td>cool, mottled, sweaty</td>
</tr>
<tr>
<td>cool and sweaty</td>
</tr>
<tr>
<td>Respiratory rate</td>
</tr>
<tr>
<td>slight increase</td>
</tr>
<tr>
<td>moderate increase</td>
</tr>
<tr>
<td>sighing respirations</td>
</tr>
<tr>
<td>Mental status</td>
</tr>
<tr>
<td>slight agitation</td>
</tr>
<tr>
<td>lethargic or uncooperative</td>
</tr>
<tr>
<td>only reacts to pain</td>
</tr>
</tbody>
</table>

* Capillary refill time > 3 seconds.

Note that blood pressure may be normal until up to 50% of the patient’s circulatory volume has been lost. The blood pressure is initially well maintained despite continuing bleeding in children and pregnant women and girls. As an indicator of haemorrhage, it can be falsely reassuring. A progressively worsening tachycardia is a more revealing feature.

A monitoring device which records pulse rate, ECG trace and blood pressure is a very useful adjunct if available.

Resuscitation of circulation
Management is focused on avoiding hypovolaemia and controlling blood loss.

Loss of blood is the most common cause of shock in major trauma.

Concealed bleeding severe enough to cause shock can occur into the pleural cavity, abdomen, pelvis and femur. Around 40% of the circulating blood volume can be lost via an open femoral fracture, wherein initial treatment should include pressure, splinting and analgesia.

Stop bleeding
The first priority is to stop obvious bleeding by applying direct pressure. Do not forget that the patient may have a wound on their back that is bleeding into the bed. To examine the back, the patient should be log-rolled, if indicated.

Injuries to the limbs: tourniquets do not work well and may cause reperfusion syndromes and add to the primary injury. The recommended procedure of ‘pressure dressing’ is an ill-defined entity. Severe bleeding from high-energy penetrating injuries and amputation wounds can be controlled by sub-fascial gauze packs placement, plus manual compression on the proximal artery, plus a carefully applied compressive dressing of the entire injured limb.

Injuries to the chest: the most common source of bleeding is chest wall arteries. Immediate placement of a chest tube drain plus intermittent suction plus efficient analgesia (IV ketamine is the drug of choice, if available) expand the lung and seal off the bleeding.

Recent evidence has shown that tranexamic acid can reduce mortality from major haemorrhage in major trauma in adults. It is also now recommended for use in children. The drug should be started as soon as possible, and within the first 3 hours after the trauma, to be effective.

In pregnancy
The loading dose is 1 gram over 10 minutes followed by an IV infusion of a further 1 gram over 8 hours.

The slow IV bolus dose is given by injecting 1 gram of tranexamic acid into a 100-mL bag of 0.9% saline and letting it run through over about 10–20 minutes (the exact timing is not crucial).

The 8-hour infusion is given by injecting 1 gram of tranexamic acid into a 500-mL bag of 0.9% saline and giving it over 8 hours (approximately 60 mL/hour). If there is a gap between the initial bolus and the subsequent infusion this probably does not matter too much, but ideally one should follow the other.

In children
The loading dose is 15 mg/kg (maximum 1 gram) diluted in a convenient volume of sodium chloride 0.9% or glucose 5% and given over 10 minutes.

The maintenance infusion rate is 2 mg/kg/hour. The suggested dilution is 500 mg in 500 mL of sodium chloride 0.9% or glucose 5% given at a rate of 2 mL/kg/hour for at least 8 hours, or until bleeding stops.

Elevate the legs if the patient is in shock.

IV fluid resuscitation
The goal is to restore oxygen delivery to the tissues. As the usual problem is loss of blood, fluid resuscitation must be a priority.

Adequate vascular access must be obtained. This requires the insertion of at least one, and ideally two, large-bore cannulae (14–16 G). Peripheral cut-down or intra-osseous infusion may be necessary.

Infusion fluids: These should be warmed to body temperature if possible (e.g. pre-warm in a bucket of warmed water or under a relative’s clothing). Remember that hypothermia can lead to abnormal blood clotting. Use crystalloids such as Ringer-lactate or Hartmann’s solution. Normal (0.9%) saline can be used if these fluids are unavailable, but be aware that, especially in larger volumes, normal saline causes a hyper-chloroaeic acidosis which is detrimental to sick or injured patients.

Avoid solutions containing ONLY glucose (e.g. 5% Dextrose in water or 5% Dextrose with 1/5N saline, these are dangerous in this situation) but glucose can be added to Ringer-lactate, Hartmann’s or N saline if there is evidence of or concern about hypoglycaemia.

Take blood for Hb, group and cross match and glucose, electrolytes and amylase for urgent analysis.
Not all cases of hypovolaemia require aggressive fluid therapy. In adults, withholding fluids in penetrating trunk trauma before achieving surgical haemostasis has been associated with an improved outcome. The rationale is to avoid pushing up the blood pressure, which hinders clot formation and promotes further bleeding. Aggressive crystalloid fluid replacement can lead to increased fluid requirements, hypothermia, dilution of clotting factors, excessive blood transfusion and its associated immunosuppression. Aim to give sufficient fluid to maintain vital organ perfusion. This can be monitored by monitoring the patient’s state of alertness which is a measure of brain perfusion in the absence of a head injury.

On the other hand, in severe head injury, cerebral perfusion is critically dependent on maintaining blood pressure. If the patient has both a severe head injury and major trunk bleeding, the apparently conflicting requirements are best managed by maintaining priorities in ABC order and achieving prompt surgical haemostasis. Beyond this strategic conflict, it should be remembered that the normal blood pressure is lower in children, hypovolaemia mimics strategic conflict, it should be remembered that the normal blood pressure is lower in children, hypovolaemia mimics. Strategic confl ict, it should be remembered that the normal blood pressure is lower in children, hypovolaemia mimics.

As outlined above, the concept of ‘targeted fluid resuscitation’ is important if the cause of hypovolaemic shock is haemorrhage from penetrating injury. Here the initial boluses of IV crystalloids required to treat shock should only be given to keep the vital organs (especially the brain, heart and kidneys) perfused before emergency surgery and blood transfusion is available. Fresh blood is particularly useful to combat the coagulopathy that occurs in major blood loss if specific coagulation components such as platelets are unavailable.

However, it must be borne in mind that penetrating trauma is not common in women and children in civilian life. We suggest that when giving boluses of crystalloid or blood to patients in shock due to bleeding in major trauma, only the amount needed to keep the blood pressure at a level sufficient to perfuse the vital organs should be given. There is no clear evidence to indicate the precise blood pressure that should be achieved in a pregnant woman or child in shock due to haemorrhage. Adequate perfusion of vital organs may best be indicated by a radial pulse which can be palpated and an alert conscious level (in the patient without a significant head injury). In pregnancy, the adequacy of the fetal heart rate may also be helpful.

In children under 2–3 years of age, the radial pulse may be difficult to feel, and the presence of a palpable brachial pulse may be the best available indicator at present.

Therefore to maintain a palpable radial pulse in pregnancy, start with IV boluses of 500 mL of crystalloid or ideally blood, and reassess after each bolus.

In children, to maintain a radial or brachial pulse give 10 mL/kg IV boluses of crystalloid or, ideally, blood, and reassess after each bolus.

In the absence of further evidence, it is recommended that in children it is best to start with 10 mL/kg boluses (infusions given as rapidly as possible) of Ringer-lactate or Hartmann’s solution or plasma expander with frequent reassessment, rather than the full 20 mL/kg recommended in other life-threatening situations, such as meningococcal sepsis or severe dehydration.

Fluid resuscitation in pregnancy starts with a 500-mL bolus of Ringer-lactate or Hartmann’s solution or plasma expander.

After repeating boluses twice (i.e. 10 mL/kg twice in a child, or 500 mL twice in pregnancy), the transfusion of blood (packed red cells) should be considered. The most important aspect of fluid resuscitation is the patient’s response to the fluid challenge.

Improvement is indicated by the following:
- a decrease in heart rate
- an increase in systolic blood pressure
- an increase in skin temperature
- faster capillary refill
- improving mental state.

Failure to improve should prompt an urgent search for chest, abdominal or pelvic haemorrhage, with the immediate involvement of an experienced surgeon. Similar volumes may be repeated if there is continuing evidence of haemorrhagic shock, after re-evaluating the state of the circulation.

It is useful to delegate the initial fluid bolus to a member of the trauma team (if a team is available), who attaches the warmed fluid bag to the IV cannula via a three-way tap to which is attached a 20- or 50-mL syringe to give the boluses.

Blood transfusion

There may be considerable difficulty in getting blood. Remember possible incompatibility, and hepatitis B and HIV risks, even among the patient’s own family.

Blood transfusion must be considered when the patient has persistent haemodynamic instability despite fluid (colloid/crystalloid) infusion. If the type-specific or cross-matched blood is not available, type O negative packed red blood cells should be used. Transfusion should be seriously considered if the haemoglobin level is less than 7 grams/dL and if the patient is still bleeding. Blood transfusion is most important, and requires blood to be taken for urgent cross-matching.

Vascular access

This is essential in all seriously injured patients. A minimum of two relatively large-bore IV cannulae is essential.

**TABLE 7.3.A.3 Infusion IV line flow rates**

<table>
<thead>
<tr>
<th>Colour code</th>
<th>Gauge</th>
<th>Crystalloid flow rate (mL/minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown</td>
<td>14</td>
<td>240</td>
</tr>
<tr>
<td>Grey</td>
<td>16</td>
<td>172</td>
</tr>
<tr>
<td>Yellow</td>
<td>17</td>
<td>130</td>
</tr>
<tr>
<td>Green</td>
<td>18</td>
<td>76</td>
</tr>
<tr>
<td>Pink</td>
<td>20</td>
<td>54</td>
</tr>
<tr>
<td>Blue</td>
<td>22</td>
<td>25</td>
</tr>
<tr>
<td>Lime green</td>
<td>24</td>
<td>14</td>
</tr>
</tbody>
</table>

Peripheral veins are preferable; the inexperienced should not attempt central venous cannulation. The external jugular vein can be accessed even in shock, but the cannula can become easily displaced and must be very carefully taped in place. A cut-down on to the long saphenous vein at the ankle can also be used. If venous access is difficult and is
taking too long, the new intra-osseous EZ-IO drill is simple to operate and can be life-saving (see Section 8.4.C), and **should be available in all emergency departments.**

Central venous cannulation can permit large volumes to be rapidly infused and also permit central venous pressure measurements. It must be undertaken by a skilled person (e.g. an anaesthetist), and a Seldinger technique should be used. The femoral vein is used for children, but not for pregnant women where the internal jugular or subclavian vein may be used. Peripheral venous access can often be established once peripheral perfusion has been improved. Both femoral venous and tibial intra-osseous access are best avoided if there is clinical evidence of a pelvic or abdominal injury. In such cases it is better to secure vascular access above the diaphragm. The upper outer aspect of the humerus can be used for intra-osseous access in that case (see Section 8.4.C).

Blood from a vein or bone marrow should be drawn for typing and cross-matching, haemoglobin, glucose and electrolytes. These tests are clinically accurate on a marrow sample from an intra-osseous approach provided there has not been prior infusion of blood or crystalloid fluid. The infused fluids should be warm. Physiological coagulation works best at normothermia, and haemostasis is difficult at core temperatures below 35°C. Hypothermia in trauma patients is common during protracted improvised outdoor evacuations, even in the tropics. It is easy to cool a patient but difficult to rewarm them, so prevention of hypothermia is essential. IV fluids should have a temperature of 40–42°C (using IV fluids at ‘room temperature’ means cooling!).

**Venous cut-down**

**Anatomical considerations**

In adults the primary site for cut-down is over the long saphenous vein above the ankle at a point approximately 2 cm anterior and 2 cm superior to the medial malleolus, but not if there is significant injury proximal to this site. Identify the surface landmarks. These are shown in Table 7.3.A.4.

**TABLE 7.3.A.4 Surface landmarks for cut-down incision**

<table>
<thead>
<tr>
<th>Saphenous</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant</td>
<td>Half a finger’s breadth superior and anterior to the medial malleolus</td>
</tr>
<tr>
<td>Small children</td>
<td>One finger’s breadth superior and anterior to the medial malleolus</td>
</tr>
<tr>
<td>Older children and pregnant mothers</td>
<td>Two finger breadths superior and anterior to the medial malleolus</td>
</tr>
</tbody>
</table>

- Apply a venous tourniquet proximal to the intended cannulation site.
- Prepare the skin with antiseptic and sterile drapes.
- Infiltrate the area with local anaesthetic (1% lignocaine using a fine 24–25G needle).
- Make a full-thickness transverse incision through the skin.
- By blunt dissection, identify and display the vein.
- Free the vein from its bed and elevate a 2 cm length.
- Pass a dissolvable suture around the proximal end of the vein but do not tie it yet.
- Introduce the plastic cannula (with trochar) through the

- **Compartments**
  - *Cardiogenic shock*
    - Inadequate heart function may result from:
      - myocardial contusion (bruising)
      - cardiac tamponade
      - tension pneumothorax (preventing blood from returning to the heart)
      - myocardial infarction.

  Assessment of the jugular venous pressure is essential in these circumstances. It will be elevated compared with hypovolaemic shock, where it may not be visible.
  - An ECG should be recorded (if available).

- **Neurogenic shock**
  - This is due to the loss of sympathetic tone, usually resulting from spinal cord injury, with the classical presentation of hypotension without reflex tachycardia or skin vasoconstriction.

- **Tension pneumothorax**
  - See under breathing section above. This can present with shock as well as breathing impairment.
Primary assessment: neurological failure

Head injury is the major cause of death in trauma.

Rapid assessment of the central nervous system for evidence of failure includes determining the AVPU score: AVPU score: A = Alert, V = responds to a Voice, P = response to Pain, U = Unresponsive.

- With a score of ‘P’ or ‘U’, intubation should take place in order to maintain and protect the airway. If there is no one skilled in intubation available, the patient should be placed in the recovery position.
- Remember to check for a pain response above the level of the clavicle, as a patient with a spinal injury may not be able to respond by moving their limbs.
- Look for signs indicative of injury (e.g. bruises, lacerations or haematoma) in the head and neck area.
- Examine the pupils for size, equality and reaction to light.
- Look for other lateralising signs, such as limb weakness or focal seizures.
- At this stage, the brain is best cared for by close attention to managing A B and C, and by correction of any hypoglycaemia.

If there is evidence of raised intracranial pressure (RICH-P):

- Intubate and ventilate to maintain oxygenation, and aim for a pCO2 of about 4 kPa.
- Maintain systolic blood pressure.
- Nurse the patient in a 30-degree head-up position.
- Contact a neurosurgeon (if available).

Mannitol 0.5 mg/kg should be administered after first excluding intracranial haematoma. If this is not excluded, there will be temporary improvement due to relief of cerebral oedema, but there may be sudden worsening a short time later due to rapid expansion of the haematoma. An alternative is hypertonic saline (see Section 7.3.C).

Low blood glucose levels are common in child trauma victims, and can cause brain damage. Always check the blood glucose level where possible. If it is not possible to check it, treat any baby or small child immediately with 5 mL/kg of 10% glucose IV.

Analgesia in major trauma (see Section 1.15)

Pain increases fear and distress, makes the patient less able to cooperate, and raises intracranial pressure. If the patient is fully conscious and in severe pain, control of pain is required.

Pain relief takes several different forms:
- Reassurance.
- Splinting of fractures.
- Covering wounds, especially burns.
- Drugs:
  - There is no place for oral or IM medication in a major trauma situation.
  - There are three alternatives in severe trauma: ketamine, morphine and Entonox.
Ketamine
The positive inotropic effects of ketamine, and the fact that it does not affect the gag reflex, make this a very helpful analgesic, especially if there is or has been shock. Repeated IV doses of 200 micrograms/kg followed by careful reassessment are usually effective, especially during transfer to a more specialised hospital (if available and relevant).

Morphine
In major trauma, 100–200 micrograms/kg morphine IV in a child, or 5–10mg in a mother, is the drug of choice, followed by careful reassessment. If the conscious level falls, the effect can be reversed with naloxone, showing whether the effect is caused by the morphine or by a worsening brain injury. If there is respiratory depression, first ventilate with a bag-valve-mask before giving naloxone.

Entonox
Entonox (a 50:50 mixture of nitrous oxide and oxygen) is useful, especially for limb injuries while splints are being applied. Do not use it in the presence of head, chest or abdominal trauma.

A head injury is NOT a contraindication to giving morphine unless there is depressed consciousness, when great care is needed.

Summary of primary assessment and resuscitation

The injured patient should have:
- a team approach with an urgent call for surgical and anaesthetic availability
- a clear airway and 100% oxygen for breathing
- adequate respiration, achieved by manual or mechanical ventilation and chest decompression when indicated
- venous access and an initial fluid challenge, if indicated on circulatory assessment
- blood sent for typing and cross-matching
- identification of the need for life-saving surgery and preparation under way
- identification of any serious head injury, and attention paid to maximising A, B and C
- cervical spine immobilisation, where appropriate

Life-threatening injuries identified and treated

<table>
<thead>
<tr>
<th>Injury</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airway obstruction</td>
<td>Head tilt, chin lift and jaw thrust, oropharyngeal airway, intubation or surgical airway</td>
</tr>
<tr>
<td>Tension pneumothorax</td>
<td>Needle thoracocentesis and chest drain</td>
</tr>
<tr>
<td>Open pneumothorax</td>
<td>Three-sided dressing, then chest drain</td>
</tr>
<tr>
<td>Massive haemothorax</td>
<td>IV access, chest drain and blood transfusion</td>
</tr>
<tr>
<td>Flail chest</td>
<td>Intubation if needed</td>
</tr>
<tr>
<td>Cardiac tamponade</td>
<td>Percardiocentesis</td>
</tr>
</tbody>
</table>

Before the secondary assessment begins, it should be remembered that:
- ABC and neurological failure components of the primary assessment and resuscitation require constant re-evaluation, as deterioration can be rapid and unexpected.
- Emergency operative treatment to control life-threatening haemorrhage should be performed promptly, without waiting for non-urgent examination and imaging.
- Identification of all anatomical injuries remains an important goal, but may be overridden by pressing physiological requirements to ensure that oxygenated blood reaches vital organs in sufficient degree. This may require emergency surgery before all non-life-threatening injuries have been identified.

Secondary assessment and emergency treatment
Secondary assessment and emergency treatment are undertaken only when the patient's ABC's are stable. If any deterioration occurs during this phase, secondary assessment must be interrupted by another primary assessment and resuscitation.

Documentation is required for all procedures undertaken. This involves careful examination from head to toe in a systematic way, including a controlled examination of the back, avoiding spinal movement by log-rolling (see Section 8.5). Clear documentation of all injuries is required, to serve as the basis of the subsequent management strategy.

Shortly after the primary assessment and resuscitation, various adjuncts help with protecting the patient and monitoring progress.

Secondary assessment: adjuncts
- Monitoring ECG, SaO₂, and blood pressure
- Urinary and gastric catheters
- Portable X-rays of chest and pelvis
- Ultrasound of abdomen (if available)
- Adequate pain control (see below)
- Baseline blood tests (especially haemoglobin, cross-matching, biochemistry and clotting)

History
- Events before and after incident
- First aid given at scene
- Past medical history
- Medications and allergies
- Immunisation status
- Last food and drink

Adjuncts to the secondary assessment and emergency treatment include:
- ECG, oxygen saturation and blood pressure monitoring (as used in primary assessment and resuscitation).
- Gastric and urinary catheters.
- Portable X-rays of the chest, neck and pelvis.

Head examination
This includes the following:
- scalp and ocular abnormalities
- external ear and tympanic membrane
- periorbital soft-tissue injuries.
Head injury patients should be suspected of having cervical spine injury until demonstrated otherwise.

**Neck examination**
- looking for a penetrating wound
- subcutaneous emphysema
- tracheal deviation
- neck vein appearance (JVP).

**Neurological examination**
- brain function assessment using the AVPU Scale or the Glasgow Coma Scale (GCS)
- spinal cord motor activity
- sensation and reflex.

**Chest examination**
- the clavicles and all ribs
- breath sounds and heart sounds
- ECG monitoring (if available).

**Abdominal examination**
- look for a penetrating wound of the abdomen requiring surgical exploration
- look for blunt trauma; a nasogastric tube is inserted (but not in the presence of facial trauma)
- rectal examination (but not in children unless absolutely essential)
- insertion of urinary catheter except in children (check meatal blood before insertion).

**Examination of pelvis and limbs**
- pain, tenderness on palpation
- deformity
- wounds.

**X-rays (if possible and where indicated)**
- chest X-ray and cervical spine films (it is important to see all seven vertebrae)
- pelvic and long bone X-rays
- skull X-rays may be useful to search for fractures when head injury is present without focal neurological deficit if CT is unavailable
- CT scans of the head and abdomen (if available).

**Head injury**

This remains the commonest cause of death and disability in severe trauma in children, and is dealt with in more detail elsewhere (see Section 7.3.C). The scalp and face are examined for bruising, abrasions, lacerations and evidence of fracture.

- Basal skull fracture is manifested by signs such as:
  - ‘raccoon eyes’ (bilateral peri-orbital haematoma), bleeding from the ears or a visible haemotympanum
  - Battle’s sign (bruising over the mastoid process, which is a relatively late sign)
  - CSF leakage from the nose, mouth or ears.

The AVPU Scale score or the Glasgow Coma Scale score is again evaluated (see Section 7.3.C), allowing a dynamic comparison with the primary assessment estimation, unless the child is now intubated and sedated.

As infants and small children are prone to hypoglycaemia, it is important to consider this as a potential cause of altered consciousness (see Section 5.8.B).

Delay in the early assessment of head-injured patients can have devastating consequences in terms of survival and patient outcome. Hypoxia and hypotension double the mortality of head-injured patients.

The following conditions are potentially life-threatening but difficult to treat in district hospitals. It is important to treat what you can with the expertise and resources that you have available, and to triage casualties carefully.

Immediate recognition and early management of the following conditions are essential:

**Acute extradural haemorrhage**
- Classical signs consist of:
  - loss of consciousness following a lucid interval, with rapid deterioration
  - a rapid rise in intracranial pressure, due to bleeding from the middle meningeal artery
  - development of hemiparesis on the opposite side, with a fixed pupil on the same side as the impact area.

The management is surgical, and every effort should be made to do burr-hole decompressions.

**Acute subdural haematoma**
- There is bleeding with clotted blood in the subdural space, accompanied by severe contusion of the underlying brain.
- This condition results from tearing of bridging veins between the cortex and the dura. Again, surgery is needed, but it requires a neurosurgeon, not burr-holes alone.

The following conditions should be treated with more conservative medical management, as neurosurgery does not usually improve the outcome:
- base-of-skull fractures
- cerebral concussion, with temporarily altered consciousness
- depressed skull fracture: an impactation of fragmented skull that may result in penetration of the underlying dura and brain
- intracerebral haematoma, which may result from acute injury or progressive damage secondary to contusion
- in children, diffuse brain swelling is a more frequent problem than bleeding; again this is managed medically, but apart from ventilation and general supportive therapy, recovery is dependent on the severity of the injury and the effect of the initial physiological support of ABC.

**Alteration of consciousness**

The most common errors in head injury evaluation and resuscitation are:
- failure to perform ABC and prioritise management
- failure to look beyond the obvious head injury
- failure to assess the baseline neurological examination
- failure to re-evaluate the patient who deteriorates.
Management of head trauma

The Airway, Breathing and Circulation are stabilised (and the cervical spine immobilised, if possible). Vital signs are important indicators of the patient’s neurological status, and must be monitored and recorded frequently.

The Glasgow Coma Scale (GCS) score is interpreted as follows:
- severe head injury: GCS score is ≤ 8
- moderate head injury: GCS score is 9–12
- minor head injury: GCS score is 13–15.

Remember:
- Deterioration may occur due to bleeding or brain swelling.
- Unequal or dilated pupils may reflect an increase in intracranial pressure.
- Head or brain injury is never the cause of hypotension in the adult trauma patient.
- Sedation should be avoided, as it decreases the level of consciousness, and promotes hypercarbia due to slow breathing with retention of CO₂.
- The Cushing response is a late sign, reflecting a lethal rise in intracranial pressure, associated with a poor prognosis. The hallmarks of the Cushing response are:
  - bradycardia
  - hypertension
  - decreased and erratic respiration.

Basic medical management for severe head injuries includes:
- Intubation and ventilation, producing normocapnia (pCO₂ in the range 4.5–5 kPa, if it is possible to monitor this). This will reduce both intracranial blood volume and intracranial pressure temporarily.
- Sedation with possible paralysis provided that the airway is fully protected by intubation and a means of assisted ventilation present.
- Moderate IV fluid input with diuresis: do not overload.
- Nursing with the head up at an angle of 20 degrees.
- Prevention of hyperthermia/fever.
- Avoidance of hypoglycaemia and electrolyte abnormalities.

Chest trauma

The majority of chest injuries result from blunt trauma, and are usually associated with injuries in other organ systems. Approximately 25% of deaths due to trauma are attributed to chest injury. Immediate deaths are essentially due to major disruption of the heart or of the great vessels. Early deaths due to chest trauma include airway obstruction, tension pneumothorax, cardiac tamponade or aspiration.

The majority of patients with thoracic trauma can be managed by simple manoeuvres and do not require surgical treatment. Respiratory distress may be caused by:
- rib fractures/flail chest
- pneumothorax
- tension pneumothorax
- haemothorax
- pulmonary contusion (bruising)
- open pneumothorax
- aspiration.

Haemorrhagic shock may be due to:
- haemothorax
- haemomediastinum.

The increased compliance of the chest wall in the child is protective, but can make interpretation of the severity of injury difficult. Rib fractures are uncommon in the infant or child, but indicate that significant blunt force has been applied. Moreover, serious chest injury can occur without obvious external signs of trauma. The energy that is not dissipated in breaking the elastic ribs may be transferred to the lungs, to be manifested as pulmonary contusion. Respiratory failure can occur quickly in infants and young children with chest trauma, yet the majority of chest injuries require no more than the insertion of an intercostal drain.

Rib fractures

Fractured ribs may occur at the point of impact, and damage to the underlying lung may produce lung bruising or puncture. The ribs usually become fairly stable within 10 days to 2 weeks. Firm healing with callus formation is seen after about 6 weeks.

Flail chest

The unstable segment moves separately and in an opposite direction from the rest of the thoracic cage during the respiration cycle. Severe respiratory distress may ensue. Treatment is by analgesia, as breathing is painful, and shallow breathing may predispose to pneumonia in this situation. In severe cases, ventilation is needed in children but not usually in adults.

Pneumothorax

- A tension pneumothorax develops when air enters the pleural space but cannot leave, increasing the compression of the underlying lung with each breath. The consequence is progressively increasing intra-thoracic pressure in the affected side, resulting in mediastinal shift. The trachea may be displaced (late sign) and is pushed away from the midline by the air under tension. The patient will become short of breath and hypoxic. Urgent needle decompression (thoracocentesis) is required prior to the insertion of an intercostal drain.

- A simple pneumothorax can be diagnosed by X-ray or ultrasound scanning and, although not life-threatening, may be associated with significant underlying lung injury. All traumatic pneumothoraces require close observation. Small ones often absorb spontaneously, but larger ones frequently require chest drainage.

Open pneumothoraces, or sucking chest wounds, allow bidirectional flow of air through a chest wall defect. The lung on the affected side is exposed to atmospheric pressure with lung collapse and a shift of the
mediastinum to the uninvolved side. This must be treated rapidly. In compromised patients, intercostal drains, intubation and positive pressure ventilation are often required. Alternatively, they can be treated by applying an occlusive dressing, taped on three sides to serve as a flap valve, followed by insertion of a chest drain remote from the site of injury. A better dressing is the customised Asherman chest seal, which consists of an adhesive ring, similar to that on a colostomy stoma bag, which projects into a pipe-shaped flap valve, resembling that in a Heimlich valve. Beware of the possibility of a tension pneumothorax developing when one of these is used.

**Pulmonary contusion**

This is usually caused by blunt trauma, and may occur in association with rib fractures with or without a fall segment. It is common after chest trauma, and is a potentially life-threatening condition. The onset of symptoms may be slow, progressing over 24 hours post-injury. Pulmonary contusion is likely to occur in cases of high-speed accidents, falls from great heights, and injuries by high-velocity bullets.

Symptoms and signs include:
- dyspnoea
- cyanosis
- sparse or absent breath sounds
- hypoxaemia
- tachycardia.

Treatment involves supplemental oxygen, careful fluid management and particular attention to pain relief. Endotracheal intubation may be necessary in severe cases.

**Traumatic haemothorax**

This is more common in penetrating than in non-penetrating injuries to the chest. If the haemorrhage is severe, hypovolaemic shock will occur, and also respiratory distress due to compression of the lung on the involved side.

Optimal therapy consists of the placement of a large chest tube and the concomitant replacement of lost blood. In some instances where the bleeding continues and is significant, open chest surgery is necessary to stop the bleeding (see below).

- A haemothorax of 500–1500 mL in pregnancy, or 10–30 mL/kg in a child, that stops bleeding after insertion of an intercostal catheter, can generally be treated by closed drainage alone.
- A haemothorax of greater than 1500–2000 mL in pregnancy, or > 30 mL/kg in a child, with continued bleeding of more than 200–300 mL per hour in pregnancy or > 5 mL/kg per hour in a child, is an indication for further investigation e.g. thoracotomy.

The injuries listed below are also possible in severe trauma, but carry a high mortality even in regional centres.

1. **Myocardial contusion:** This is associated, in blunt chest trauma, with fractures of the sternum or ribs. The diagnosis is supported by abnormalities on ECG and elevation of serum cardiac enzymes (if available). Cardiac contusion can simulate a myocardial infarction. The patient must be closely observed, with cardiac monitoring (if available). This type of injury is more common than is often realised, and may be a cause of sudden death some time after the accident.

2. **Pericardial tamponade:** Penetrating cardiac injuries are a leading cause of death in young men in some notorious urban areas, but rare in other settings. It is rare to have pericardial tamponade with blunt trauma. Pericardiocentesis must be undertaken early if this injury is considered likely (see Section 8.4.B for method). Look for pericardial tamponade in patients with:
   - shock
   - distended neck veins
   - no pneumothorax
   - muffled heart sounds.

3. **Thoracic great vessel injuries:** Injury to the pulmonary veins and arteries is often fatal, and is one of the major causes of on-site death.

4. **Rupture of the trachea or major bronchi:** This is a serious injury with an overall estimated mortality of at least 50%. The majority (80%) of the ruptures of bronchi are within 2.5 cm of the carina.

The usual signs of tracheobronchial disruption are:
- haemoptysis
- dyspnoea
- subcutaneous and mediastinal emphysema
- occasionally cyanosis.

**Trauma to the oesophagus**

This is rare in patients with blunt trauma, and more frequent in association with penetrating injury. It is lethal if unrecognised, because of mediastinitis. Patients often complain of sudden sharp pain in the epigastrium and chest, with radiation to the back. Dyspnoea, cyanosis and shock occur, but these may be late features. Urgent IV broad-spectrum antibiotics covering both aerobic and anaerobic organisms, as well as nil-by-mouth nursing, are required.

**Diaphragmatic injuries**

These may occur in association with either blunt or penetrating chest trauma, paralleling the rise in frequency of road traffic accidents. The diagnosis is often missed.

Diaphragmatic injuries should be suspected in any penetrating thoracic wound which is:
- below the fourth intercostal space anteriorly
- below the sixth interspace laterally
- below the eighth interspace posteriorly.

These injuries are more commonly seen on the left side.

**Thoracic aorta rupture**

This occurs in patients who are exposed to severe decelerating forces, such as high-speed car accidents or a fall from a great height. It has a very high mortality due to rapid exsanguination; the total adult blood volume of 5 litres may be lost in the first minute following injury.

**Abdominal trauma**

Abdominal injuries are common and, if recognised, may prove fatal. Any patient involved in any serious accident should be considered to have an abdominal injury until it has been ruled out.

Severe visceral injuries occur more frequently in children than in adults especially to the liver because of its relative size and lack of protection by the ribs in the young child.
Unexplained blood loss evident during the primary assessment may be due to intra-abdominal haemorrhage.

The abdomen is a classical silent area after trauma. It has to be actively cleared of injury rather than simply noted to be soft and non-tender, especially in the face of altered consciousness.

Cardiovascular decompensation may occur late and precipitously.

The organ most commonly injured in penetrating trauma is the liver, and in blunt trauma the spleen is often torn and ruptured. This is especially the case in children, in whom these organs are poorly protected by ribs and muscles, and especially where chronic illness may cause enlargement and fragility of the liver and spleen.

Thorough history taking and a careful examination of the abdomen may give clues to the origin of bleeding or perforation.

Gastric distension may cause respiratory embarrassment, and a gastric tube should be placed.

In order to gain the cooperation of a frightened child, place the examiner’s hand over the mother’s hand to undertake palpation.

There are two basic categories of abdominal trauma:

1 Penetrating trauma, where the need for surgical consultation is urgent. For example:
   - gunshot
   - stabbing
2 Non-penetrating trauma. For example:
   - compression injuries
   - crushing injuries
   - seat-belt injuries
   - acceleration/deceleration injuries.

About 20% of trauma patients with acute haemoperitoneum have no signs of peritoneal irritation at the first examination, and repeated primary assessment must be undertaken.

Blunt trauma can be very difficult to evaluate, especially in the unconscious patient. These patients may need a peritoneal lavage although where ultrasound and/or abdominal CT is available, peritoneal lavage has been superseded. However, an exploratory laparotomy may be the best definitive procedure if abdominal injury needs to be excluded.

Complete physical examination of the abdomen includes rectal examination (although this should be avoided in children as a routine, and only performed if clinically indicated), assessing:
   - sphincter tone
   - integrity of the rectal wall
   - blood in the rectum
   - prostate position in adults.

Remember to check for blood at the external urethral meatus.

Women and girls of childbearing age should be considered pregnant until pregnancy has been excluded. The fetus may be salvageable, and the best treatment of the fetus is resuscitation of the mother. A pregnant mother at term, however, can usually be resuscitated properly only after delivery of the baby. This difficult situation must be assessed at the time (see Section 1.13).

The diagnostic peritoneal lavage (DPL) may be helpful for determining the presence of blood or enteric fluid due to intra-abdominal injury. The results can be highly suggestive, but it is overstated as an important diagnostic tool. If there is any doubt, a laparotomy is still the gold standard.

The indications for DPL include:
   - unexplained abdominal pain
   - trauma of the lower part of the chest
   - hypotension, and a fall in haematocrit with no obvious explanation
   - any patient with abdominal trauma who has an altered mental state
   - any patient with abdominal trauma and spinal cord injuries
   - pelvic fractures.

The relative contraindications to DPL are:
   - pregnancy
   - previous abdominal surgery
   - operator inexperience
   - if the result would not change your management (e.g. if laparotomy is planned).

Other specific issues with regard to abdominal trauma

- Pelvic fractures are often complicated by massive haemorrhage and urological injury.
- It is important to examine the rectum for the presence of blood and for evidence of rectal or perineal laceration (see above for the approach in children).
- X-ray of the pelvis may be valuable, if clinical diagnosis is difficult.

The management of pelvic fractures includes:
   - resuscitation (ABC)
   - transfusion
   - immobilisation and assessment for surgery
   - analgesia.

In a severely injured child, a urinary catheter should be inserted. This may be omitted in small babies and in less severely injured children. Small boys are particularly prone to urethral stenosis after catheterisation. If the mechanism of injury is of concern, it is important to exclude renal tract injury by examining the first urine for red blood cells.

Management of severe abdominal injury

Abdominal ultrasound (and CT scanning, if available) have become invaluable adjuncts to the secondary assessment, not only for diagnosing intra-abdominal injury, but also for monitoring progress when a defined injury is being managed conservatively.

Bleeding from solid organs may not show up immediately in the resuscitation room, and evidence of hollow-organ rupture may take 24 hours or more to show as free fluid on ultrasound. This commits the trauma team to a high index of suspicion well beyond the classical ‘golden hour’. This phrase indicates the importance of prompt identification and resuscitation of Airway, Breathing or Circulation problems that, without intervention, would lead to further damage from hypoxia and hypovolaemia being suffered by the injured patient.

Patients with refractory shock, penetrating injuries or signs of perforation require laparotomy.

Other injuries may be managed conservatively. After
initial fluid transfusion, an experienced surgeon may decide that bleeding from an injured spleen, liver or kidney does not require immediate operative intervention. CT scanning (if available) is an invaluable aid to decision making.

Splenic injury is relatively common, and can occur after relatively minor trauma, especially if the spleen is enlarged following an inflammatory process or infection, notably malaria. Signs include left upper quadrant pain and tenderness, with referred pain to the shoulder tip. Non-operative management is used frequently in many centres, but long-term problems of splenectomy are insignificant by comparison with the potential consequences of inadequate supervision of conservative management which requires careful monitoring and fluid management on-site, round-the-clock theatre, anaesthetic and surgical availability: all of which are difficult to provide in a low resource setting.

Increasingly, liver injuries are also being managed conservatively. Unlike the relatively straightforward operation of splenectomy, operative liver repair or resection is hazardous, and packing plays a major role in the operative management of uncontrolled hepatic bleeding.

Injuries to the retroperitoneal organs, such as the kidneys or pancreas, may present with vague or atypical signs, again requiring a high index of suspicion. A significant kidney injury does not always cause demonstrable haematuria.

Ultrasound studies and dynamic contrast CT scans (if available) may provide valuable information on renal structure and function, but false-negative results commonly occur. Intravenous urography remains useful for demonstrating the details of renal and ureteric injury, especially in centres without a CT scanner. Pancreatic injury may occur with a normal amylase level, and the amylase level may be raised in the absence of pancreatic damage.

Spinal trauma (see Section 4.2.D)
Management of spinal cord injuries is particularly difficult in resource-limited settings, where spinal surgery may not be available within the country. Usually patients in these settings have not been handled carefully during transport from the site of injury to the hospital. Decisions have to be made as to whether or not cervical spinal immobilisation is appropriate, especially if it could interfere with airway resuscitation.

Spinal injury should be ruled out in any patient who has been subject to a mechanism of injury capable of damaging the spine. This seemingly obvious statement highlights the fact that it is often surprisingly difficult to ascertain whether there has been an injury to the spine or not, particularly in the face of a concomitant head injury, or in a child who is too young to communicate.

Even in an alert older child, distracting pain from a limb injury may lead the patient to ignore and deny neck pain, even when a spinal fracture exists. Radiological clearance in children is further complicated by the difficulty of interpreting X-rays of immature bones (see Section 7.3.B), and by the relative laxity of ligaments, which gives rise to pseudo-subluxation.

Be aware of the significant incidence of spinal cord injury without radiological abnormality (SCIWORA) in children.

Spinal injury is less common in children than in adults, partly because of the elasticity of the bones and ligaments. This same elasticity contributes to the different patterns of spinal injury that are seen. In the cervical spine, for example, injuries tend to occur at a higher level than in adults, and often span several segments rather than dissipating energy in fracturing a single vertebra.

Examination of potentially spine-injured patients must be carried out with the patient in the neutral position (i.e. without flexion, extension or rotation), and without any movement of the spine.

The patient should be:
- log-rolled
- properly immobilised (using in-line immobilisation, a stiff neck cervical collar or sandbags)
- transported in the neutral position.

With vertebral injury (which may overlie spinal cord injury), look for:
- focal tenderness
- deformities, as well as (for a posterior spinal cord injury) oedema.

Clinical findings pointing to injury of the cervical spine include:
- difficulties in respiration (diaphragmatic breathing; check for paradoxical breathing)
- flaccidity, with no reflexes (check the rectal sphincter)
- hypotension with bradycardia (without hypovolaemia).

The entire spine should be palpated during a log-roll, when the patient is turned on to their side in a controlled way, keeping the spine in line. The presence of palpable steps, bogginess or tenderness should be noted. The limbs should be examined for sensory and motor signs of focal or segmental deficit.

Neurological assessment
Assessment of the level of injury must be undertaken. If the patient is conscious, ask him/her questions relevant to their sensation, and ask them to try to make minor movements, to enable you to assess motor function of the upper and lower extremities.

Key reflex assessment to determine the level of the lesion is summarised below.

Motor response
- Diaphragm intact level C3, C4, C5
- Shoulder shrug C4
- Elbow flexion (biceps) C5
- Wrist extension C6
- Elbow extension C7
- Wrist flexion C7
- Abduction of fingers C8
- Active chest expansion T1-T12
- Hip flexion L2
- Knee extension L3-L4
- Ankle dorsiflexion L5-S 1
- Ankle plantarflexion S1-S2

Sensory response
- Anterior thigh L2
- Anterior knee L3
- Anterolateral ankle L4
- Dorsum great and 2nd toe L5
- Lateral side of foot S1
- Posterior calf S2
- Peri-anal and perineal sensation S2-S5
If no sensory or motor function is exhibited, with a complete spinal cord lesion, the chance of recovery is small. A diaphragmatic breathing pattern, bradycardia, hypertension, peripheral vasodilatation and priapism suggest spinal cord injury. Throughout the primary and secondary assessments, precautions for spinal protection should ideally be maintained, using a hard collar and side-supports (blocks and straps or sandbags and tape), except for airway procedures and local examination, when manual in-line immobilisation is reinstated.

If the patient is alert, able to communicate clearly and has no distracting pain from another injury, the spine can be cleared clinically without resorting to X-rays. Otherwise, ideally spinal precautions are maintained until radiological clearance is achieved and the patient is re-examined.

If possible, three X-rays of the cervical spine should be taken: cross-table lateral view with arm traction to reveal the C7-T1 interface; antero-posterior view and transoral odontoid peg view. These must be assessed by an experienced professional (if available), paying particular attention to the soft tissues as well as the bony structures (see Section 7.3.B).

If the mechanism of injury warrants it, thoracic and lumbar views are also required.

If the lower cervical spine is not adequately visualised on the lateral view, oblique views are requested. If the X-rays are inadequate or show suspicious areas, CT scanning (if available) is recommended to confirm or exclude a fracture. The MRI scan provides a better examination of neural, ligamentous and other soft tissues, although its sensitivity reveals minor as well as major tissue injury, making interpretation more difficult. It remains expensive and is not universally available. The MRI scanner is a frightening environment for an unsedated child, and the powerful magnetic field creates challenging logistical problems for the monitoring equipment applied to the patient.

Other neurological injuries include damaged nerves to peripheral nerves.

Pelvic trauma
Pelvic injury remains a potentially life-threatening injury, especially if it is associated with a large retroperitoneal haematoma, or if the fracture site communicates with the rectum. External fixation of the pelvis may be valuable in controlling major venous haemorrhage.

Arterial bleeding may be controlled by embolisation (if available). The suitability of these techniques depends on the particular configuration of the fracture. It may be difficult to distinguish retroperitoneal haemorrhage from intraperitoneal haemorrhage, the latter requiring laparotomy.

In the absence of suitable equipment, tight compressive binding of the pelvis may help bleeding vessels to clot, although this is not practical in the presence of advanced pregnancy.

The purpose of pelvic binding is to reduce the volume of the pelvis thus tamponading any haemorrhage, as well as providing biomechanical stabilisation. This can be achieved by wrapping a folded sheet around the pelvis. The sheet should centre on the greater trochanters and extend to the iliac crests. Taping the thighs or the feet together also helps maintain the anatomical position of the pelvis.

Not all pelvic trauma is serious. Some pubic rami fractures are minor injuries, with little intervention required. Nevertheless, the pelvis is a ring structure that tends to break in two places. On inspecting the pelvic X-ray, careful attention should be paid to the sacro-iliac joints and sacral foramina, to seek subtle evidence of a second break in the ring.

Limb trauma
In general, limb fractures in children are more likely to be managed conservatively than those in adults, reflecting the child's capacity to heal, and the risk of interfering with growth plates. An understanding of the Salter–Harris classification of epiphyseal fractures is essential, and access to a radiological atlas of developmental stages is helpful (see Section 7.2).

Examination must include:
- skin colour and temperature
- distal pulse assessment
- grazes and bleeding sites
- limb's alignment and deformities
- active and passive movements
- unusual movements and crepitations
- the severity of pain caused by injury.

Management of extremity injuries

Aim to:
- keep blood flowing to peripheral tissues
- prevent infection and skin necrosis
- prevent damage to peripheral nerves.

Special issues relating to limb trauma
Stop active bleeding by applying direct pressure, rather than by using a tourniquet, as the latter can be left on by mistake, and this can result in ischaemic damage.

Open fractures
Any wound situated in the vicinity of a fracture must be regarded as a communicating one.

Principles of the treatment are to:
- stop external bleeding
- immobilise, and relieve pain.

Amputated parts of extremities (such as fingers) should be covered with sterile gauze towels which are moistened and put into a sterile plastic bag. A non-cooled amputated part may be used within 6 hours after the injury, and a cooled one as late as 18–20 hours after it. This practice is only worthwhile if facilities for reimplantation are available.

Early fasciotomy
Compartment syndrome is fairly common, and often underestimated. This condition is caused by an increase in the internal pressure of fascial compartments, which may result from crush injuries, fractures, intramuscular haematomas or amputations. This causes compression of vessels, with resultant hypoperfusion and hypoxia of tissues, including peripheral nerves.

Compartment syndrome is recognised by the following signs in a fractured or otherwise injured limb:
- pain, accentuated by passive stretching of the involved muscles
- decreased sensation
- swelling
Blunt trauma may lead to:
- haemorrhage from abdominal organs, notably the spleen and liver
- uterine irritability and premature labour
- partial or complete uterine rupture

Pelvic fractures may be associated with severe blood loss.

**What are the priorities?**
- Assessment and resuscitation according to the ABC and neurological failure structured approach.
- Resuscitation in the left lateral position after 20 weeks' gestation, to avoid aortocaval compression: remember the left lateral tilt.
- Assessment of fundal height and tenderness, and fetal heart rate monitoring as appropriate.
- Vaginal examination or speculum examination to assess vaginal bleeding, cervical dilatation and rupture of membranes.

If placenta praevia is known or suspected, digital vaginal examination should not be performed, as major haemorrhage may occur. Careful speculum examination is acceptable.

It is important to be alert to signs of hypovolaemia, which are delayed in pregnancy as the mother has a higher circulating volume. Hypovolaemia may compromise the fetus before the mother’s vital signs become abnormal. A fall in maternal blood pressure is a late and ominous sign.

Resuscitation of the mother may save the baby as well. There are times when the mother’s life is at risk and the fetus may need to be delivered in order to save the mother.

**Action plan**
1. Call for the most senior help available.
2. Perform standard primary assessment and resuscitation.
3. In addition:
   - Assess fetal well-being. Use ultrasound examination to detect the fetal heart rate and to identify any retroplacental or intra-abdominal bleeding. Ultrasound is also useful for ascertaining the presentation of the fetus; transverse lie may suggest rupture of the uterus.
   - Consider whether Caesarean section is indicated for maternal or fetal reasons.

**Indications for Caesarean section (if facilities are available to perform it safely)**

These include the following:
- cardiac arrest
- uterine rupture
- inadequate exposure during laparotomy for other abdominal trauma
- placental abruption
- an unstable pelvic or lumbo-sacral fracture with the patient in labour
- fetal distress with a viable fetus

**Peri-mortem Caesarean section**

This should be undertaken when maternal cardiac output has not been restored by initial cardiopulmonary resuscitation (CPR). Delivery should ideally be accomplished within 5 minutes of cardiac arrest.

The rationale behind peri-mortem Caesarean section is as follows:
Pathway of care: trauma in pregnancy.

Primary assessment and resuscitation

| Airway: | increased risk of aspiration – early gastric tube |
| Breathing: | if chest drain is needed, place at higher level (3rd or 4th intercostal space) |
| Circulation: | left lateral tilt |
| Abnormalities in pulse rate, blood pressure and capillary refill are late because of hypervolaemia of pregnancy |
| Targeted resuscitation’ with IV crystalloids, colloïd or blood |
| Neurological failure: | convulsions may be due to eclampsia as well as head injury |

Secondary assessment and emergency treatment:

Assess for:
- Ruptured uterus and placental abruption after blunt trauma to abdomen (including seat-belt injury). Uterine tenderness, vaginal bleeding, shock all occur. They may be indistinguishable clinically. Scan may show fetal death or intra-abdominal fluid (blood)
- Rupture of membranes (by speculum)
- Fetal distress
- Evidence of intra-abdominal bleeding or injury to abdominal organs

Consider bowel injury (compressed by uterus and therefore more vulnerable to blunt trauma or penetrating injuries)

Ensure anti-tetanus measures
X-rays as needed
On discharge from hospital, patient to report abdominal pain, decreased fetal movements, vaginal bleeding or fluid leakage

Increased oxygen requirement. However, most injuries can be identified by careful assessment, and managed with simple measures, including left lateral tilt and facial oxygen.

Special issues with regard to major trauma in children

Trauma is a leading cause of death for all children, with a higher incidence in boys. The survival of children who sustain major trauma depends on the severity of the trauma, effective pre-hospital care and early resuscitation. The initial assessment of the paediatric trauma patient is identical to that of the adult. The first priority is the Airway, Breathing and Circulation, then early neurological assessment, and finally exposing the child for full examination, without loss of heat.

TABLE 7.3A.5 Paediatric ‘normal’ values are helpful as follows:

<table>
<thead>
<tr>
<th>Variable</th>
<th>&lt; 1 year</th>
<th>1–2 years</th>
<th>2–5 years</th>
<th>5–12 years</th>
<th>&gt; 12 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate (beats/minute)</td>
<td>110–160</td>
<td>100–150</td>
<td>95–140</td>
<td>80–120</td>
<td>60–100</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg) 50th centile</td>
<td>80–90</td>
<td>85–95</td>
<td>85–100</td>
<td>90–110</td>
<td>100–120</td>
</tr>
</tbody>
</table>

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Specific resuscitation and intubation issues in children

- The head, tongue and nasal airway are relatively large.
- The angle of the jaw is greater, the larynx is higher and the epiglottis is proportionally larger and more “U” shaped.
- The cricoid is the narrowest part of the larynx, which limits the size of the endotracheal tube. By adulthood, the larynx has grown and the narrowest part is at the cords.
- Obligatory nose breathing occurs in small babies.
- The trachea in the full-term newborn is about 4 cm long, and will admit a 2.5 or 3.5 mm diameter endotracheal tube. (The adult trachea is about 12 cm long.)
- Gastric distension is common following resuscitation, and a nasogastric tube is useful for decompressing the stomach.

If tracheal intubation is required, avoid using cuffed tubes in children under 10 years of age, so as to minimise subglottic swelling and ulceration. Oral intubation is easier than nasal intubation for infants and young children.

Shock in the paediatric patient

The femoral artery in the groin and the brachial artery in the antecubital fossa are the best sites at which to palpate pulses in the child. If the child is pulseless, cardiopulmonary resuscitation should be commenced.

Signs of shock in paediatric patients include:

- tachycardia
- weak or absent peripheral pulses
- capillary refill time > 3 seconds
- tachypnoea
- agitation
- drowsiness
- poor urine output.

Hypotension is a late sign, even in the presence of severe shock.

A normal urine output is 1–2 mL/kg/hour for the infant and 0.5–1 mL/kg/hour in the older child.

Hyperthermia is a major problem in children because of their relatively large surface area. They lose proportionally more heat through the head. All fluids should be warmed. Exposure of the child is necessary for assessment, but cover them as soon as possible.

Continuing care for patients who have suffered major trauma

Tetanus prophylaxis

This is often forgotten in the management of severe trauma. In the fully immunised patient, an additional booster will depend on a clinical decision as to the possibility of exposure to contamination, the severity of injury and the timing of the last tetanus immunisation. In an unimmunised or incompletely immunised patient, tetanus immunoglobulin should be given and a full course of or a completing course of tetanus toxoid started (using a different limb to the one receiving the immunoglobulin).

Guidance on tetanus-prone wounds

These include the following:

- compound fractures
- deep penetrating wounds
- wounds containing foreign bodies (especially wood splinters)
- wounds complicated by pyogenic infections
- wounds with extensive tissue damage (e.g. crush injuries, contusions or burns)
- any wound that is obviously contaminated with soil, dust or horse manure (especially if topical disinfection is delayed for more than 4 hours).

<table>
<thead>
<tr>
<th>History of tetanus vaccination</th>
<th>Type of wound</th>
<th>Tetanus vaccine booster (see below)</th>
<th>Tetanus immunoglobulin</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 3 doses &lt; 5 years since last dose</td>
<td>All wounds</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>5–10 years since last dose</td>
<td>Clean minor wounds</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>All other wounds</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>&gt; 10 years since last dose</td>
<td>All wounds</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>&lt; 3 doses or uncertain</td>
<td>Clean minor wounds</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>All other wounds</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Transfer

Not every hospital has the resources and expertise to safely care for injured pregnant women or girls and children. Ideally, children with serious injuries should be transported directly from the scene of the accident to a centre with such capability (if one exists in the country). Even then, geographical constraints may render transfer unsafe.

Patients should be transported only if they are going to a facility that can provide a higher level of care.

Even when the transfer is urgent, it is essential to achieve physiological stability before embarking on a hazardous journey in the isolated environment of the ambulance. There is always physiological deterioration during transfer. Thorough assessment should take place prior to transfer, to exclude coexisting life-threatening conditions which may be amenable to treatment on site. For example, a child with a head injury should not be transferred in a hypotensive condition caused by unrecognised and untreated intra-abdominal bleeding.

It is essential that there is effective communication with:

- the receiving centre
- the transport service
- escorting personnel
- the patient and their relatives.

Communication between the referring and admitting clinicians is necessary, not only to agree that transfer is indicated, but also to establish guidelines for care in...
transit, and to warn the receiving centre when the patient is expected to arrive.

Effective stabilisation necessitates:
- prompt effective initial resuscitation
- control of haemorrhage and maintenance of the circulation
- immobilisation of fractures
- analgesia.

If the patient deteriorates, re-evaluate them by using the primary assessment, checking and treating life-threatening conditions, and then make a careful assessment focusing on the injuries area.

Inter-hospital transfer requires careful planning, to provide:
- trained medical and nursing escorts
- simple compact robust equipment
- drugs for resuscitation, sedation, pain relief and muscle relaxation
- fluids and blood products if indicated
- a suitable vehicle and ambulance staff.

In trauma care, some transfers are time-limited (e.g. to evacuate an extradural haematoma). In such cases, the extra time taken for a retrieval team to reach the referring hospital may offset the benefit of their specialised skills.

Peri-operative care in major trauma

In the operating theatre, definitive anatomical reduction, repair or resection of individual injuries takes place. While the surgical team focuses on anatomical correction, the anaesthetic team maintains physiological system control. The impetus and sense of urgency evident in the Emergency Department should be maintained, without losing the thoroughness necessary to manage all aspects of care.

If the patient has a significant head injury, the anaesthetic agents should be chosen to avoid increasing intracranial pressure or cerebral blood flow. In general, this means avoiding high doses of volatile agents such as halothane or isoflurane. Ketamine has long been considered to be contraindicated in head injury, although there is recent evidence that challenges this view. It may be the only anaesthetic available.

If the child is undergoing lengthy extracranial surgery in the face of a severe head injury, it is wise to observe the pupils at frequent intervals.

Maintaining the child’s core temperature is a key aim during prolonged surgery. Hypothermia impairs platelet function and increases the risk of infection, although it has been claimed to help to preserve brain function in severe head injury.

High-dependency care

In the immediate management of the injured patient, the focus was on physiological assessment and intervention using an ABC structured approach, followed by anatomical assessment and definitive care.

When high-dependency care is instituted, physiological stabilisation again becomes the main concern, although it is important to remain alert to the possibility of any further injuries that were not evident in the secondary assessment.

Detailed physiological control is facilitated by monitoring and good nursing.

See Section 1.14 for further information.

Step-down care and rehabilitation

High-dependency care, acute ward care and rehabilitation serve to minimise disability, rather than influence mortality, which is already largely determined by this time. The emphasis shifts towards integration back into normal life, physically and psychologically, although the course may be interrupted by further reconstructive surgery.

### 7.3.B Emergency trauma radiology

#### Introduction

Essential initial trauma films to screen for major injuries include the following.

- lateral cervical spine radiograph
- chest X-ray
- pelvic X-ray.

These should only be taken after immediately life-threatening injuries have been identified and treated (resuscitation).

The ABCD approach to X-ray interpretation is as follows:

- Adequacy, Alignment and Apparatus.
- Bones.
- Cartilage and soft tissues.
- Disc spaces (in the spine), Diaphragm (in the chest).

First, all X-ray films should be checked for adequacy. Do they include all of the part that needs imaging? Is the film a proper antero-posterior view or is it at an angle? If the film is not of reasonable quality, interpretation is difficult and may be faulty.

#### Cervical spine

The cervical spine should be immobilised (see Section 7.3.A) before any radiology. The standard film is a lateral radiograph, which may be supplemented by an AP (lower cervical spine and odontoid peg views) if appropriate.

Bony injury is not the primary focus in spinal injury. The main concern is to delineate actual or potential injury to the cord, as any unstable fracture, if inadequately immobilised, may lead to progressive cord damage.

A normal lateral cervical X-ray film may be falsely reassuring. The plain film only shows the position of the bones at the time when the film was taken, and gives no idea of the magnitude of flexion and extension forces applied to the spine at the time of injury. The cord may be injured even in a child without any apparent radiographic abnormality. This phenomenon is known as SCIWORA (see below).

Unlike adult spine injuries, most paediatric cervical spine injuries occur either through the discs and ligaments, at the cranio-vertebral junction (C1, C2 and C3), or at C7/T1. The relatively large head of the child, moving on a flexible neck
with weaker muscles, leads to injury in the higher cervical vertebrae.

Children show three patterns of spinal injury:
1. subluxation or dislocation without fracture
2. fracture with or without subluxation or dislocation
3. spinal cord injury without radiographic abnormality (SCIWORA).

The last of these, SCIWORA, is said to have occurred when radiographic films are completely normal in the presence of significant cord injury. If the film is normal in a conscious child with clinical symptoms (such as pain, loss of function or paraesthesia in a limb), neck protection measures should be continued. In an unconscious child at high risk, a cord injury cannot be excluded until the patient is awake and has been assessed clinically, even in the presence of a normal cervical spine film. Adequate spinal precautions should be continued until the child is well enough to be assessed clinically.

The most common site of a ‘missed’ spinal injury is where a flexible part of the spine meets the fixed part. In the neck these are the cervico-cranial junction and the cervico-thoracic junction.

The whole spine should be viewed from the lower clivus down to the upper body of T1 vertebra.

Alignment

When studying a cervical spine X-ray, look for the four lines shown in Figure 7.3.B.1. These lines should be uninterrupted. If there is a ‘step’ in any line, the spinal cord is at risk. The cervical immobilisation must be continued and an orthopaedic opinion sought.

The four lines are as follows:
1. anterior vertebral line
2. posterior vertebral line (anterior wall of the spinal canal)
3. facet line
4. spino-laminar line (posterior wall of the spinal canal).

Figure 7.3.B.2 shows an actual cervical spine X-ray with three of the lines delineated and the odontoid, a facet joint, a spinous process and a lamina identified. The gaps between the adjacent spinous processes and between each facet joint should be similar. Again, any discrepancy is suggestive of a potentially unstable spine.
Cartilage and soft tissues
Abnormal widening of the pre-vertebral soft tissues may indicate a haematoma due to cervical spine injury. However, there may be a significant spinal injury with normal soft tissues. Thus the absence of soft-tissue swelling does not exclude major bony or ligamentous injury. When a child is intubated, it is difficult to assess pre-vertebral soft-tissue swelling. Small children have large adenoids, which are seen as well-demarcated soft tissue swelling at the base of the clivus.

Acceptable soft-tissue thicknesses are as follows:
- above the larynx: less than one-third of the vertebral body width
- below the larynx: not more than one vertebral body width.

Below the level of the larynx, the pre-vertebral soft tissues become progressively narrower towards the cervico-thoracic junction (see Figure 7.3.B.4). If the pre-vertebral soft tissues are wider at C7 than at the C5 level, this suggests trauma at the C7/T1 level.

Any soft-tissue swelling outside these limits should be regarded as abnormal, and neck protection measures maintained until a further clinical opinion can be obtained. In small children the soft tissues may appear abnormally wide if the film is taken with the infant lying in flexion. If in doubt, maintain the neck protection and ask for advice.

Discs
The height of the vertebral disc should be compared from C2/C3 to C7/T1. The discs should all be of similar height, as shown earlier in Figure 7.3.B.1. Any significant discrepancy suggests a crush fracture of the vertebrae (usually caused by a fall from a height);

Flexion and extension cervical spine films should never be performed in the acute trauma situation.

Chest X-ray
Adequacy and alignment
Adequacy can be assessed by evaluating both radiographic penetration and the depth of the patient’s inspiration. The film should just show the disc spaces of the lower thoracic vertebrae through the heart shadow. At least five anterior rib ends should be seen above the diaphragm on the right side. If the film is taken in expiration, it may mimic a chest infection. Films are difficult to take in young children, as they are unable to ‘hold their breath’ on command, so the radiographer has to try to take the picture at the moment of full inspiration.

Alignment can be assessed by ensuring that the medial ends of both clivices are equally spaced about the spinous processes of the upper thoracic vertebrae. Abnormal rotation may create an apparent mediastinal shift. The trachea should be equally spaced between the clivices.

Apparatus
Check the position of any apparatus, including the following:
- tracheal tube
- central venous lines
- chest drains.

Misplacement of the endotracheal tube (ETT) into a bronchus should be evident clinically, but may be seen on a chest film if you look for it. Do this first when reviewing any chest X-ray on an intubated patient. Ventilation of only one lung will lead to hypoxia in a compromised patient.

The ideal position for an ETT is below the clivices and at least 1 cm above the carina. To find the carina, identify the slope of the right and left main bronchi. The carina is where the two lines meet in the midline.

Bones
Look at each rib in detail. This can be done by tracing out the upper and lower borders of the ribs from the posterior costochondral joint to the point where they join the anterior costal cartilage at the mid-clavicular line. The individual internal bone patterns can then be assessed.

The ribs in children are soft and pliable, and only break when subjected to considerable force. Even greater force is required to fracture the first rib or to break multiple ribs. Consequently, the presence of these fractures should stimulate you to look for other sites of injury both inside and outside the chest. Fractures in children’s rib bones are hard to see while fresh unless there is displacement. Diagnosis is often made a week or so later if an X-ray is taken then, when the calcifying new callus is seen.

Finish assessing the bones by inspecting the visible vertebrae and the clivices, scapulae and proximal humeri. Thoracic spine injuries may be overlooked on a chest radiograph. Abnormal flattening of the vertebral bodies,
widening of the disc spaces, or gaps between the spinous processes or pedicles may be seen. On the antero-posterior views, increased vertical or horizontal distances between the pedicles or spinous processes indicate an unstable fracture, as shown in Figure 7.3.B.5.

If there are rib fractures in the first three ribs, these may be associated with major spinal trauma and great vessel injury.

**Cartilage and soft tissues**

**Lungs**

In a well-centred film, the lungs should appear equally black on both sides. Compare the left and right lungs in the upper third, middle third and lower third of the chest.

Check that the lungs go all the way out to the rib cage (i.e. that there is no pleural effusion or pneumothorax). A lung that is black on one side may be due to a pneumothorax or air trapping. A lung that is white on one side may be due to collapse, pulmonary haemorrhage, contusion or effusion (including haemothorax).

On the supine film, blood or fluid lies posteriorly, giving a generalised greyness to the lung, rather than the typical meniscus sign seen on the erect film. At the apex of each lung, an effusion displacing the lung downward may indicate spinal injury or major vessel damage.

A suspected tension pneumothorax should be treated clinically in the emergency situation, without confirmatory X-ray.

On a supine film, the air in a simple pneumothorax rises anteriorly and may only be evident from an abnormal blackness or ‘sharpness’ of the diaphragm or cardiac border. The standard appearances of a pneumothorax, where there is a sharp lung edge and the vessels fail to extend to the rib cage and the lung edges, may not occur in the supine film.

**The heart**

The cardiac outline should lie one-third to the right of the midline and two-thirds to the left of the midline. If the film is not rotated, which should be checked, mediastinal shift is due to the heart being either pushed from one side or pulled from the other. For example, mediastinal shift to the left may be due to a pneumothorax, air trapping or effusion on the right side, or collapse of the left lung.

All emergency major trauma X-rays are taken in the supine position because of the seriousness of the patient’s condition, often using portable X-ray machines. The X-ray tube is near to the patient and the heart is anterior with the film posterior. The heart in this situation appears abnormally magnified (widened), and the cardiothoracic ratio is difficult to assess on supine AP films.

The mediastinal cardiac outline should be clear on both sides. Any loss of definition suggests consolidation (de-aeration) of adjacent lungs. A ‘globose’ shape to the heart may suggest a pericardial effusion. Tamponade is managed clinically. A cardiac ultrasound scan is useful in equivocal cases.

**The upper mediastinum**

In the teenager the mediastinum should appear as narrow as in an adult. In children under the age of 18 months, the normal thymus is large, causing a confusing and often ‘sail-shaped’ upper mediastinal shadow. A normal thymus may touch the right chest wall, left chest wall, left diaphragm or right diaphragm, making it very difficult to exclude mediastinal pathology. Fortunately, mediastinal widening due to aortic dissection or spinal trauma is very rare in small children.

In the older child involved in trauma, mediastinal widening may mean aortic dissection, or major vessel or spinal injury. Ultrasound scanning will be helpful (if available).

**Diaphragms**

The cardiophrenic and costophrenic angles should be clear on both sides. The diaphragms should be clearly defined on both sides, and the left diaphragm should be clearly visible behind the heart. Loss of definition of the left diaphragm behind the heart suggests left lower lobe collapse, an abnormal hump suggests diaphragmatic rupture, and an elevated diaphragm suggests effusion, lung collapse or nerve palsy.

At the end of the systematic ABCD review of the X-ray, check again in the key areas shown in the following list:

- Behind the heart: left lower lobe consolidation or collapse.
- Apices: for effusions, pneumothorax, rib fractures and collapse or consolidation.
- Costophrenic and cardiophrenic angles: fluid or pneumothorax.
- Horizontal fissure: fluid or elevation (upper lobe collapse).
- Trachea for foreign body (and ETT).

**Pelvic X-ray**

A single, antero-posterior pelvic view is sufficient.

**Adequacy and alignment**

It is very important to have the pelvic film positioned as a true antero-posterior (AP) view, as rotation causes interpretation problems. In a true AP film the tip of the sacrum will be aligned with the symphysis pubis.

The whole of the pelvis from the top of the iliac crests to the ischial tuberosities and both hip joints should be seen. The femoral necks shown to the level of the trochanters should be included.

**Bones**

The pelvis is composed of the sacrum, innominate bones (iliac wings), ischium and pubic bones. These come together to form a ‘Y’ shaped cartilage in the floor of the acetabulum. In young children, the joint between the ischium and the pubis (ischiopubic synchondrosis) is commonly seen and may simulate a fracture.
The pelvis is reviewed as a number of rings on the two-dimensional film. These include the pelvic brim, the two obturator rings and both acetabular fossae. The rings should appear smooth and symmetrical in a well-centred film (see Figure 7.3.B.6, which shows a normal child pelvis). The femoral necks must be checked for fracture. Figure 7.3.B.7 shows a pelvis with multiple fractures, at major risk of serious pelvic bleeding as large vessels are torn with the force shown by the widespread fractures.

**Cartilage and soft tissues**

Minor rotation, hip flexion or rotation will distort the fat plane and make assessment of soft-tissue displacement difficult. Abnormal widening of the obturator fat pad may indicate a pelvic side wall haematoma.

The paediatric pelvis is held together by cartilage. Separation through the cartilage of the sacro-iliac joint, the symphysis pubis or the “Y” cartilage of the acetabular floor may occur without apparent bony injury. Comparison of both hips and sacro-iliac joints on a well-centred film may show this. On a well-centred film the distance between the femoral head and the floor of the acetabulum “crescent” should be symmetrical – it is abnormal in effusion or dislocation of the hip joint.

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### 7.3.C The child with a head injury

#### BOX 7.3.C.1 Minimum standards

- ABC and neurology and maintenance of oxygenation and blood pressure with control of environmental temperature while exposing and examining the whole patient.
- Emergency burr-hole by an experienced operator if available.
- Parenteral antibiotics.
- Mannitol or hypertonic saline (2.7% or 3%).
- Anticonvulsants.

**Scores for best motor response (6)**

1. None
2. Extension to pain (decerebrate)
3. Flexion to pain (decorticate)
4. Withdrawal from pain
5. Localises pain
6. Obeys commands

**Scores for best eye response (4)**

1. None
2. Eye opening to pain
3. Eye opening to verbal command
4. Eyes open spontaneously

**Scores for best verbal response (5)**

1. Alert, babbles, usual words
2. Less than usual words spontaneous irritable cry
3. Cries only to pain
4. Moans to pain
5. No response to pain

**Children’s Coma Scale**

**Scores for best motor response (6)**

1. Spontaneous or obeys verbal command
2. Localises to pain or withdraws to touch
3. Withdraws from pain
4. Abnormal flexion to pain (decorticate)
5. Abnormal extension to pain (decerebrate)
6. No response to pain

Another factor that must be documented is pupillary size.
and reaction to light. This helps when lateralising brain injury and its progress.

**Major diffuse brain injury**

Cerebral oedema is the most likely pathological process following serious head injury in children. Intracranial haematomas are quite uncommon in childhood; they are more likely to be found in an adult patient. Even the presence of unequal pupils in a seriously head-injured child may be a false localising sign, and does not have the same significance that this sign has in the adult head-injured patient.

The only measures that are of proven value are maintenance of adequate oxygenation and perfusion and the avoidance of adverse effects (see below). Removal of intracranial haematomas, if identified, is very helpful, but this pathology is much less frequently found in the paediatric population, where cerebral oedema predominates. A CT scan (if available) will identify any haematoma.

**Artificial ventilation, tracheostomy and more sophisticated medical measures designed to control raised intracranial pressure may be of value, but require evacuation to a fully equipped and staffed children's neurointensive care unit.**

In the absence of such a facility, the best strategy is to concentrate on optimising the care of the unconscious patient with attention to:

- preservation of the airway
- maintenance of adequate ventilation
- avoidance of hypotension by maintaining the circulating volume with normal Ringer-lactate or Hartmann's solution
- the maintenance of appropriate fluid and electrolyte balance, avoiding hypotonic IV fluids, hyponatraemia and hypoglycaemia
- avoidance of fever > 38°C. Use rectal paracetamol: child 1–5 years 125–250 mg/dose up to 4 doses in 24 hours; 5–12 years 250–500 mg/dose maximum 4 doses; 12 years–adult 500 mg/dose maximum 4 doses
- maintaining the patient in a 20-degree head-up position with no neck flexion and with the head in the midline
- if there is deterioration of the GCS score, giving an IV infusion of mannitol 0.25–0.5 g/kg
- mannitol can be repeated later but there is a decreasing response to this treatment. Alternatively, hypertonic saline can be used (2.7% or 3% at a dose of 3 mL/kg). This may not be associated with a 'rebound' brain swelling as occurs with mannitol and does not induce a diuresis like mannitol but rather augments plasma volume
- care of the skin, bladder and bowel.

Fluid restriction is not indicated, but fluid overload should be avoided.

If transfer or evacuation is required within the first 48 hours after injury, endotracheal intubation and mechanical ventilation are desirable. Steroids are of no value and increase the risk of intercurrent infection. Antibiotics are reserved for patients with evidence of sepsis. Anticonvulsant drugs are only given if there are seizures.

**Intracranial haematoma**

Only 6 in 1000 patients will develop a significant intracranial haematoma following a non-missile head injury. The most useful guide to the development of an intracranial haematoma is deterioration in the level of consciousness. The presence of inequality of the pupils will help to identify the lesion. The ideal investigation is CT (if available). If CT is not readily available, burr-hole exploration on the same side as the injury as the dilated pupil and the opposite side to any motor weakness is justified in the hope of finding an extradural or subdural clot. However, burr-holes must only be made by a skilled surgeon using appropriate equipment.

Emergency temporary reduction of raised intracranial pressure can be achieved by one or more of the following medical measures:

- mannitol 20% by IV infusion over 20 minutes (0.25–0.5 g/kg). This can be repeated as required but response becomes progressively lessered
- Alternatively, hypertonic saline can be used (2.7% or 3% at a dose of 3 mL/kg). This may not be associated with a 'rebound' brain swelling as occurs with mannitol and does not induce a diuresis like mannitol but rather augments plasma volume
- intubation and artificial ventilation to keep PaCO₂ around 4 KPa.

An extradural clot will always be beneath the site of trauma. The place to make the burr-hole is therefore at the site of any external site of injury. This may be known from the history, or may be found by shaving the entire scalp in search of bruises, grazes, lacerations or soft-tissue swelling. A plain skull radiograph (if available) may show a fracture, and if so the burr-hole should be made at the site of the fracture. If there are none of the above-mentioned clues, then 'blind' burr-hole exploration will be required. This should commence on the side of the dilated pupil, or on the side of the pupil that dilated first.

Three standard burr-holes can be made: subtemporal, frontal and parietal. It is crucial to make the sub-temporal burr-hole low enough in the middle cranial fossa. The correct position is immediately above the zygoma at the midpoint between the outer canthus of the eye and the external auditory meatus. If an extradural clot is found, the burr-hole must be extended as either a cranietomy or a craniotomy. The margins should extend sufficiently far to uncover the entire clot, which can then be evacuated by suction. Bleeding meningeal arteries can be controlled with diathermy or by under-running with a suture. Bleeding from major venous sinuses can be controlled by haemostatic gauze and by hitching the adjacent dura to the surrounding pericranium with sutures. Diffuse meningeal oozing will stop spontaneously if it is not tampered with: the application of hydrogen peroxide or warm saline packs may help. When the clot has been evacuated and the bleeding has stopped, it is essential to hitch the dura around the perimeter of the bone opening to the adjacent pericranium in order to prevent recurrence. In very young children, it may be better to pass sutures through small drill holes in the surrounding bone. If a craniotomy has been made, the bone flap is replaced.

If no extradural haematoma is found at any of the burr-hole sites, the dura should be opened cautiously. If there is a subdural clot, a craniotomy is necessary. It is safer to make multiple short dural incisions rather than a wide dural...
opening. It is difficult to be certain whether a tense dura is
due to subdural clot or brain swelling. Most acute subdural
clots are associated with quite severe brain injury, and a
wide dural opening is very likely to be followed by massive
uncontrollable extrusion of the brain material.

Post-operatively, anaesthesia can be reversed unless
the patient is to be evacuated to another facility. If a sig-
nificant clot has been found, there should be a prompt
improvement in the level of consciousness.

In a baby with severe signs of rapidly progressive raised
intracranial pressure following a closed head injury, it is
reasonable to search for an acute subdural haematoma
by passing an adult (18-gauge) lumbar puncture needle
into the subdural space through the anterior fontanelle or
through a diastased coronal suture. The baby is wrapped
in a sheet and held supine by an assistant so as to secure
the head, the arms and the trunk. The entry point is either
at the most lateral extremity of the anterior fontanelle or at
a point in line with the pupil, whichever is the furthest from
the midline. In a conscious child, local anaesthesia must first
be applied. The needle is passed at a shallow angle, in an
anterior direction, through the skin and then through the
relatively resistant dura. The trochar is removed from the
needle and any subdural fluid allowed to drain spontane-
ously. The needle is then withdrawn and the puncture hole
in the skin closed with a suture.

**Skull fractures**

Most skull fractures heal without treatment, but they should
be observed for 24 hours in case an intracranial haema-
toma occurs unless a CT scan has shown no intracranial
bleeding. Fractures which are compound, either externally
(i.e. the overlying scalp is broken) or internally (i.e. there
is a fracture into a paranasal sinus or into the middle ear)
require attention.

**Externally compound fractures**

- Like all wounds, these should be explored to remove
  all dead tissue and foreign material. This is the most
effective means of preventing infection. Operation should
be performed as soon as possible. Simple wounds can
be explored under local anaesthetic, but more complex
wounds will require general anaesthesia.
- Depressed fractures may require elevation to ensure
  that the full extent of the wound, including the brain
  substance, has been cleaned and that the dura is
  repaired if it has been torn. If the wound is less than
  24 hours old and not heavily contaminated, the bone
  fragments can be replaced. If the wound is older than
  24 hours or is heavily contaminated, it is safer to discard
the bone fragments.
- Antibiotics are not generally required, as it is the mechan-
  ical debridement of the wound that is the crucial step.
However, compound depressed skull fractures that have
occurred in any setting, especially an agricultural or
rural one, may be contaminated with *Clostridium tetani*
and are best covered with 5 days of IV benzylpenicillin
(for children aged 1 month to 12 years, 50 mg/kg
every 6 hours by slow injection, and for those over
12 years, 2.4 grams every 6 hours) with anti-tetanus
active immunisation and toxoid as appropriate (see
Section 7.3.A). Animal bites, especially from dogs, will
be contaminated with *Pasteurella multocida* and should
be covered with ampicillin IV (40 mg/kg 8-hourly up to a
maximum of 4 grams/day). If surgery is delayed for more
than 24 hours, antibiotics should be given.

The scalp has excellent vascularity and every effort should
be made to preserve scalp. Once significant areas are
lost, complex skin flaps will be required. Split-skin grafts
will not take on bare calvarial bone. If substantial areas of
full-thickness scalp are lost, as in burns or attacks by large
animals, a useful technique is to make multiple burr-holes,
leaving the dura intact. Over the course of a few weeks the
florid granulation tissue that grows out of the burr-holes will
form a satisfactory base to accept split-skin grafts.

**Internally compound fractures**

- These carry the risk of CSF fistula and meningitis.
- Prophylactic antibiotics are not indicated.
- Most CSF rhinorrhoea or otorrhoea will resolve sponta-
  neously, but cases persisting for longer than 2 weeks will
  require formal repair. This will involve referral to a higher
  centre with facilities for CT scanning and neurosurgical
  expertise.
- Meningitis complicating traumatic CSF rhinorrhoea or
  otorrhoea is usually caused by *Streptococcus pneu-
  moniae*, and should be treated for 2 weeks with IV
  benzylpenicillin (at the dose stated above) or IV cefo-
taxime (for children under 12 years, 50 mg/kg every
6 hours and for those over 12 years 1–3 g every 6 hours.
It is an absolute indication for surgical repair to prevent
further episodes.

**Penetrating injuries**

Children are especially prone to suffering penetrating injuries
because of the thin nature of the immature skull, especially
around the orbit. **Such wounds require exploration through
their full extent to prevent brain abscesses.**

Missile injuries require removal of all foreign material
wherever feasible. High-velocity penetrating brain injuries
from modern military weapons are invariably fatal because
of the extreme forces involved, and these patients, along
with those who are in deep coma following even low-velocity
 gunshot wounds, will not make a useful recovery, so only
 palliative care is appropriate.

**Early traumatic epilepsy**

Epileptic seizures in the first 48 hours after injury are com-
mon in children. Except in infants they do not, in isolation,
indicate the presence of an intracranial haematoma. Most
seizures are self-limiting and simply require airway protec-
tion. An anti-epileptic drug should be given to prevent
further fits. It is important to remember that the child with
an acutely injured brain will be exquisitely sensitive to the
respiratory depressant effects of diazepam or lorazepam.
These are best avoided unless there is no alternative, when
they must be used to stop the convolution, which will worsen
defects of the head injury.

When using either diazepam or lorazepam, always have a
functioning bag-mask resuscitator immediately available.
The main side effect of these drugs is apnoea or hypoven-
tilation, but it is short-lived, and a few minutes of bagging
with the bag-mask will result in spontaneous respiration
restarting. The safest drug is paraldehyde administered
per rectum (0.4 mL/kg up to 1 year of age, then one mL
per year of age up to a maximum of 10 mL). Unfortunately,
it is becoming increasingly difficult to obtain as it is not
manufactured widely. Paraldehyde can be diluted with an equal volume of olive oil. It can be given using a plastic syringe if given immediately, otherwise by glass syringe. Do not use paraldehyde if it has a brown colour or smells of acetic acid.

A longer-acting drug must also be given at the same time and maintained. The most appropriate are phenobarbitone for children aged less than 5 years (load 15 mg/kg slowly IV, then a total of 5 mg/kg/day starting dose up to a maximum of 6 mg/kg/day IV, or orally in two divided doses 12 hours apart) and phenytoin for those aged over 5 years, administered IV initially (load 15 mg/kg IV over 20 minutes, followed by a further 10 mg/kg IV over a further 20 minutes if the first dose is unsuccessful). Then give 2.5 mg/kg every 12 hours IV over 20 minutes initially, increasing up to a maximum of 7.5 mg/kg every 12 hours (with each dose given over 20 minutes if IV). Phenytoin can also be given orally.

7.3.D Electrical injury

**BOX 7.3.D.1 Minimum standards**

- ABC.
- ECG monitoring.
- Sodium bicarbonate.

**Introduction**

Electrical injuries usually occur in the home, and involve relatively low currents and voltage. The mortality from electrical injuries from high-power external sources such as electrified railways is high, and death is immediate.

Other injuries may occur during the event. For example, the patient may fall or be thrown. Therefore a full trauma assessment must be undertaken.

**Pathophysiology**

Alternating current (AC) produces cardiac arrest at lower voltages than does direct current (DC). Regardless of whether the electrocution is caused by AC or DC, the risk of cardiac arrest is related to the size of the current and the duration of exposure. The current is highest when the resistance is low and the voltage is high.

**Current**

The typical effects of an increase in current are as follows:

- **Above 10 mA:** Tetanic contraction of muscles may make it impossible for the patient to let go of the electrical source.
- **Above 50 mA:** Tetanic contraction of the diaphragm and intercostal muscles leads to respiratory arrest, which continues until the current is disconnected. If hypoxia is prolonged, secondary cardiac arrest will occur.
- **From 100 mA to 50 A:** Primary cardiac arrest may be induced. (The defibrillators that are used in resuscitation deliver around 10 A.)
- **From 50 A to several 100 A:** Massive shocks cause prolonged respiratory and cardiac arrest and more severe burns. A lightning strike is a massive direct current of very short duration which can depolarise the myocardium and cause an immediate asystole.

**Resistance**

The resistance of the tissues determines the path that the current will follow. Generally, the current will follow the path of least resistance from the point of contact to earth. The relative resistance of the body tissues is, in increasing order, as follows: tissue fluid, blood, muscle, nerve, fat, skin, bone. Electrocuton generates heat, which causes a variable degree of tissue damage. Nerves, blood vessels, the skin and muscles are damaged most. Swelling of damaged tissues, particularly muscle, can lead to a crush or compartment syndrome that requires fasciotomy. Water decreases the resistance of the skin and will increase the amount of current that flows through the body.

**Voltage**

High-voltage sources such as lightning or high-tension cables cause extremely high currents and severe tissue damage. However, very high voltages can cause severe superficial burns without damaging deeper structures (flash burns and arcing).

**Primary assessment and resuscitation**

Call for help and disconnect the electricity in a safe manner.

- Be aware that high-voltage sources can discharge through several centimetres of air.

**Airway**

The upper airway should be opened and secured, especially if this is compromised by facial or other injuries. The cervical spine should be immobilised if there is a strong possibility of an unstable fracture.

**Breathing**

If the patient is not breathing, give rescue breaths using a mouth-to-mouth technique if no equipment is available (e.g. in the home) and, if available, a bag and mask with high-flow oxygen through an attached reservoir. If the patient is breathing but cyanosed, or low oxygen saturation is present, give inspired oxygen to maintain \( \text{SaO}_2 \) (if a pulse oximeter is available) in the range 94–98%.

**Circulation**

If the patient appears lifeless despite the rescue breaths, commence chest compressions and continue cardiopulmonary resuscitation (CPR) as described in Section 1.12 until help arrives. In the resuscitated or non-arrested patient who has been brought to hospital, after ABC assessment and management, the entry and exit point of the current should be sought in order to gain a picture of the sort of possible internal injuries that could have occurred. Children with significant internal injuries have a greater fluid requirement than one would suspect on the basis of the area of the external electric burn.
Secondary assessment and emergency treatment

Other injuries should be treated in an appropriate and structured manner (see Section 7.3.A).

Associated injuries are common in electrocution. Almost all possible injuries can occur as a result of falls or being thrown from the source. Burns are particularly common, and are caused either by the current itself or by burning clothing. Tetanic contraction of muscles can cause fractures, subluxations or muscle tearing.

Other problems

Burns cause oedema and fluid loss. Myoglobinuria occurs after significant muscle damage, and acute renal failure is a possibility. In this case, it is important to maintain a urine output of more than 2 mL/kg/hour in a child or 60 mL/kg/hour in a pregnant woman or girl with the judicious use of diuretics such as mannitol and appropriate fluid loading. Alkalisation of the urine with sodium bicarbonate, 1 mmol/kg in a child (1 mL/kg of 8.4% solution or 2 mL/kg of 4.2% solution) or 50 mmol in pregnancy increases the excretion of myoglobin.

Arrhythmias can occur up to a considerable time after the electrocution, and continuous ECG monitoring is helpful (if available).

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7.3.E Drowning

**Box 7.3.E.1 Minimum standards**

- ABCD and early basic life support.
- Early management of hypothermia: radiant heat/hot-water bottles.
- Low-reading thermometer.
- Orogastric or nasogastric tube.
- High-dependency care (if available).

**Introduction**

**Definition**

‘Drowning’ is defined as ‘a process resulting in primary respiratory impairment from submersion/immersion in a liquid medium’. According to WHO data, in 2004 there were 388,000 known deaths as a result of drowning worldwide, although the WHO considers this to be a massive underestimate. For children under the age of 15 years, drowning is the leading cause of accidental death worldwide. The low- and middle-income countries account for 96% of unintentional drowning deaths, and over 60% of the world’s drowning events occur in the Western Pacific Region and South-East Asia, although the above figures do not include the massive loss of life from floods and tsunamis and from water transport accidents.

**Pathophysiology**

Bradycardia and apnoea occur shortly after submersion as a result of the diving reflex. As apnoea continues, hypoxia and acidosis cause tachycardia and a rise in blood pressure. Between 20 seconds and 5 minutes later, a breakpoint is reached, and breathing occurs. Fluid is inhaled and on touching the glottis causes immediate laryngeal spasm. After a variable but short period of time the laryngospasm subsides and fluid is aspirated into the lungs, resulting in alveolitis and pulmonary oedema. Hypoxia is by this time severe and the patient will have lost consciousness. Bradycardia and other dysrhythmias can also occur and may be fatal (ventricular fibrillation is rare).

Hypoxia is thus the key pathological process that ultimately leads to death, and needs to be corrected as quickly as possible.

Children who survive because of interruption of this chain of events not only require therapy for drowning, but also assessment and treatment of concomitant hypothermia, hypovolaemia and injury (particularly spinal). Major electrolyte abnormalities due to the amount of water swallowed seldom occur.

The type of water is associated with infections with unusual organisms, and aspiration of water contaminated with petroleum products can lead to a severe respiratory distress syndrome.

Submersion injuries are generally associated with hypothermia. The large body surface area to weight ratio in infants and children puts them at particular risk. Hypothermia may have a protective effect against the neurological sequelae following hypoxia and ischaemia, but is also associated with life-threatening dysrhythmias, coagulation disorders and susceptibility to infections.

The initial approach to the drowning patient focuses on the correction of hypoxia and hypothermia, and the treatment of associated injuries, which are common in older children and often overlooked. Cervical spine injury should always be suspected in drowning victims for whom the mechanism of injury is unclear, although these are rare (0.5% overall, and much rarer in children under 5 years).

Remember:

- Small children can drown in small volumes of water (e.g. in a bucket or shallow pool).
- Not all drowning is accidental (consider the possibility of abuse or neglect).
- Other injuries may be present.
- Other illnesses may have resulted in the drowning (e.g. epilepsy).
- Consider the possibility of drug or alcohol abuse.

**Properties of water**

- Water can be fresh (hypotonic) or salty (hypertonic).
- Water can conceal hidden dangers, such as trauma, entrapment, tide and flow, and contamination.
- Water can act as a solid at high-impact velocity.
- Water may be only one of several problems affecting the child (consider alcohol, drugs, child abuse, epilepsy, trauma, etc.).

**Problems that may be present at drowning**

- Hypothermia.
Primary assessment and resuscitation

Call for help and move the victim from the water as quickly as possible without risk to the rescuer, in order to allow CPR and ABC to proceed.

Rescue of the victim in a vertical position may lead to cardiovascular collapse due to venous pooling. However, horizontal rescue in the water must not be allowed to delay the rescue.

The initiation of early and effective basic life support is vital. ABC reduces the mortality drastically and is the most important factor for survival. Five rescue breaths must be given as early as possible even in shallow water, if this can be done without risk to the rescuer. Mouth-to-nose ventilation may be easier in this situation. Basic life support (see Section 1.12) then proceeds according to the standard paediatric or maternal algorithm, even in hypothermia. The presence of cardiac arrest can be difficult to diagnose, as pulses are difficult to feel. If there are no signs of life, chest compressions should be started and continued with a rate of 15 compressions to two breaths.

Airway and manual in-line cervical spine control (if there is a major suspicion of unstable neck injury) are the first steps. Following submersion, the stomach is usually full of swallowed water. The risk of aspiration is therefore increased, and the airway must be secured as soon as possible on arrival at a healthcare facility. The best airway protection is usually provided by endotracheal intubation using a rapid sequence induction, once in a hospital setting. Following this, an oro- or nasogastric tube should be inserted.

Breathing: commence and continue mouth to mouth or mouth to mouth and nose ventilation.

Circulation: commence and continue chest compressions in the ratio 15 compressions to 2 ventilations until a satisfactory output is achieved, confirmed by palpation of a pulse or signs of life (i.e. breathing, movement or gagging). Keep the victim as warm as possible. Remove wet clothing and wrap in dry garments/towels if this can be done by bystanders without interrupting CPR.

If in a hospital setting or professional help has arrived, advanced life support protocols can be followed if necessary (see Section 1.13). Respiratory deterioration can be delayed for 4–6 hours after submersion, and even children who have initially apparently recovered should be observed for at least 8 hours. Keep the oxygen saturation in the range 94% or higher. Once the circulation is restored, take blood for haemoglobin, electrolytes (if available) and cross-matching. If the patient is in shock, give 10 mL/kg of Ringer-lactate or Hartmann's solution. Reassess and repeat if required. Give fluids warmed to body temperature if possible.

Disability and neurological examination (AVPU scale).

Exposure and temperature control: the core temperature measurement is best taken with a low-reading thermometer.

Secondary assessment and emergency treatment

Ensure that there are no other injuries requiring treatment. Examine the patient from head to toe. Any injury may have occurred during the incident that preceded immersion, including spinal injuries (see Sections 4.2.D and 7.3.A). Older children or pregnant women may have ingested alcohol and/or drugs.

Hypothermia

A core temperature reading should be obtained as soon as possible, and further cooling prevented. Hypothermia is common following drowning, and adversely affects resuscitation attempts unless it is treated.

The advantages of endotracheal intubation in hypothermia (if a skilled person is available) outweigh the small risk of precipitating arrhythmias. Not only are arrhythmias more common, but some, such as ventricular fibrillation, may be refractory to treatment at temperatures below 30°C, when defibrillation should be limited to three shocks (see Section 1.13) and inotropic or anti-arrhythmic drugs should not be given.

If defibrillation is unsuccessful, the patient should be warmed to above 30°C as quickly as possible, when further defibrillation may be attempted. The dose interval for resuscitation drugs is doubled between 30°C and 35°C. Resuscitation should be continued until the core temperature is at least 32°C or cannot be raised despite active measures.

Once above 32°C the temperature should ideally rise by 0.25–0.5°C per hour to reduce haemodynamic instability. Most hypothermic patients are hypovolaemic. During rewarming, vasodilatation occurs, resulting in hypotension which requires warmed IV fluids, but it is important not to give too much and risk circulatory overload and pulmonary oedema. Continuous monitoring of the pulse rate, respiratory rate and liver size, and auscultation of the lungs looking for crepitations that might suggest pulmonary oedema, are essential. Therapeutic hypothermia (32–34°C) for at least 24 hours has been shown to improve the neurological outcome in some patients, and may be of benefit in children who remain comatose, but requires high-level intensive care facilities.

Rewarming strategies

External rewarming

- Remove cold wet clothing.
- Supply warmed dry blankets.
- If these are not immediately available, place the child in skin-to-skin contact with an adult (kangaroo-type care).
- Warm air system (fan heaters).
- Heating blanket.

Core rewarming

- Warm IV fluids to 39°C to prevent further heat loss.
- Beware rewarming shock. Do not allow the temperature to rise > 37°C.

Monitoring

- Core temperature.
Prophylactic antibiotics are often given after immersion in severely contaminated water. Fever is common during the first 24 hours, but is not necessarily a sign of infection. Gram-negative organisms, especially *Pseudomonas aeruginosa*, are common, and *Aspergillus* species have been reported. If an infection is suspected, broad-spectrum IV antibiotic therapy (e.g. cefotaxime) should be started after blood and sputum cultures (if available).

Keeping the patient normoglycaemic is important for the neurological outcome.

**Prognosis**

The outcome is determined by the duration of hypoxic–ischaemic injury and the adequacy of initial resuscitation. It is assumed that hypoxic brain damage is reduced when the brain cools before the heart stops. No single factor can predict good or poor outcome in drowning reliably. However, the following factors may give an indication of outcome.

**Immersion time**

Most children who have been submerged for more than 10 minutes have a very small chance of intact neurological recovery or survival.

**Time to basic life support**

Starting basic life support at the scene greatly reduces mortality, whereas a delay of more than 10 minutes is associated with a poor prognosis.

**Time to first respiratory effort**

If this occurs within 3 minutes after the start of basic cardiopulmonary support, the prognosis is good. If there has been no respiratory effort after 40 minutes of full cardiopulmonary resuscitation, there is little or no chance of survival unless the child’s respiration has been depressed (e.g. by hypothermia, medication or alcohol).

**Core temperature**

Pre-existing hypothermia and rapid cooling after submersion also seem to protect vital organs and can improve the prognosis. A core temperature of less than 33°C on arrival and a water temperature of less than 10°C have been associated with increased survival. This effect is pronounced in small children because of their large surface area to weight ratio.

**Persistent coma**

A persistent GCS score of less than 5, or a score of U on the AVPU scale, indicates a poor prognosis.

**Type of water**

Whether the patient was in salt or fresh water has no bearing on the prognosis.

**When to stop resuscitation**

- Immersion time: most children who do not recover have been submerged for more than 10 minutes.
- If the first gasp occurs between 1 and 3 minutes after cardiopulmonary resuscitation, the prognosis is good.
- Intact survival has been reported after cold submersion for 1 hour.
- Survival has been reported after 6.5 hours of cardiopulmonary resuscitation.
- A child has been revived from a body temperature of 15°C but cool-water drowning does not have the protection offered by ice-cold water.
- Failure to restore a perfusing rhythm within approximately 30 minutes of rewarming to 32–35°C makes further efforts unlikely to be successful.
- Resuscitation should not be discontinued until the core temperature is at least 32°C or cannot be raised.

Resuscitation should only be discontinued out of hospital if there is clear evidence of futility, such as massive trauma or rigor mortis.

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7.3.F Heat stroke and hypothermia

**Box 7.3.F.1 Minimum standards**

**Heat stroke**

- ABC.
- Ice packs.
- Fans.

**Hypothermia**

- Skin-to-skin contact with carer.
- Warm blankets and clothing.
- Heated blanket.
- Infra-red warming lamp

**Heat stroke**

**Clinical signs**

- Confusion.
- Tachycardia.
- Fever (> 40°C)
- Hot dry skin.
- Tachypnoea.
- Hypotonia.

**Pathophysiology**

- Neurological impairment.
- Renal insufficiency.
- Disseminated intravascular coagulation.
- Acute respiratory failure.
May have underlying infection predisposing to heat stroke.

Treatment
- **Urgent cooling:** Aim to cool the patient within 30 minutes. Remove clothes, spray with cool water, use a fan if available, and apply ice packs to the neck, axillae and groin. It is especially important to cool the head.
- Provide system support as necessary.
- Give fluids intravenously, especially if there is respiratory failure.
- Give oxygen.
- In hot climates, each hospital should have a cool room (ice or air-conditioned) for emergency treatment.

Hypothermia: prevention and treatment
Hypothermia occurs in association with drowning, and it may also occur during sepsis, especially in the very young child. Malnourished children in particular have a low metabolic rate. The thermoneutral temperature is 28–32°C. At 24°C they can become hypothermic. Those with infection or extensive skin lesions are at particular risk. A hypothermic malnourished child should always be assumed to have septicaemia.

Signs
The signs of hypothermia are a core temperature (<35.5°C with low reading thermometer). If axillary temperature is <35°C or does not register, assume hypothermia.

Routine prevention
- Cover all sick children with clothes and blankets unless they are febrile.
- Keep the ward doors and windows closed to avoid draughts.
- Avoid wet nappies, clothes or bedding.
- Do not wash very ill children. Others can be washed quickly, ideally with warm water, and dried immediately.
- Avoid making a sick or injured child cold when undertaking medical examinations.

Emergency treatment of hypothermia
- Immediately place the child on the carer’s bare chest or abdomen (skin to skin) and cover both of them. Give the mother a hot drink to increase her skin blood flow.
- If no adult is available, clothe the child very well (including the head) and put them near a lamp or radiant heater, or use a warming blanket if one is available.
- Immediately treat for hypoglycaemia (see Section 5.8.B), and then start normal feeds if appropriate to the child.
- Consider sepsis, and give condition- and age-appropriate antibiotics.
- Monitor the temperature every 60 minutes until the temperature is normal (>36.5°C).

### 7.3.G Landmine injuries

**Box 7.3.G.1 Minimum standards**
- ABC resuscitation.
- Shock management.
- Analgesia.
- Anti-tetanus immunisation and immunoglobulin.
- Prostheses that are changed as the child grows.

**Patterns of injury**
- Injuries caused by stepping on to a buried blast mine or improvised explosive device (IED): traumatic amputation of the detonating limb, with fragment and minor blast damage to the other leg (most common injury).
- Injuries caused by fragmentation landmine or IED: widespread fragment injury to the limbs and trunk.
- Injuries caused by close-proximity detonation of a landmine or IED in the hand or close to the face: amputation of the hand or arm, plus damage to the face, eyes and head. Usually occurs in mine cleaners or in those handling weapons.

Some mines are scattered from aircraft or by shells to lie on the surface of the ground. These weapons are unstable and likely to explode when handled. Unexploded ordnance, such as grenades, can also explode if handled, resulting in the same pattern of injury. Recently IEDs have been placed next to roads and pathways, causing similar injuries.

**Specific problems in children**
- Children sustain a higher level of injury per gram of explosive than adults, because of their smaller body mass. A small antipersonnel mine of approximately 30 grams, which would normally require a below-knee amputation in an adult, may result in an above-knee amputation in a child.
- Children are susceptible to close-proximity detonation injuries, because of their tendency to pick up and play with objects that they find.

**Treatment**
- Initial surgical management follows the basic principles of resuscitation (see Section 7.3.A).
- In injury caused by stepping on a buried blast mine or IED, airway maintenance is not usually a problem, as the child is frequently conscious.
- As with all injured children, fear and bewilderment due to pain and the unfamiliar surroundings can be distressing for all involved.
- In close-proximity detonation injury, airway maintenance can be a problem. The patient is often unconscious and there may be damage to the upper airway from the blast. A tracheostomy may be required.
- Benzylpenicillin and anti-tetanus toxoid should be administered in all cases.
- Anaesthesia can be achieved using a ketamine infusion (see Section 1.15 for pain relief).
Injury from stepping on a buried blast mine or IED: technique of amputation

- On the operating table, a thorough wash with warm clean water and a scrubbing brush will get rid of the gross contamination and general soiling of the limbs prior to formal skin preparation.
- Always use an above-knee orthopaedic tourniquet to minimise peri-operative blood loss, which is proportionally greater in children than in adults.
- Perform a standard amputation according to International Committee of the Red Cross surgical guidelines. Remember the following points:
  - The muscles are usually contused more proximally by blast damage than may be initially apparent.
  - Dirt and contamination can be propelled up tissue planes by the blast. An amputation through the blast damage can leave contamination in the wound.
  - Make a bulky myoplasty to cover the bone end using the medial gastrocnemius below the knee, or the medial vastus above the knee. Leave generous skin flaps, as the muscle in the stump will swell considerably post-operatively.
  - Make an anterior bevel to the bone when dividing it, and file the edges down.
  - Let the tourniquet down when the amputation is completed, to check haemostasis before applying the dressing.

7.3.H Gunshot wounds

### BOX 7.3.H.1 Minimum standards

- ABC resuscitation.
- Shock.
- Analgesia.
- Anti-tetanus immunisation and immunoglobulin.
- Penicillin.
- X-rays and ultrasound.
- High dependency care.

Introduction

Although the end of the Cold War led to a reduction in the risk of conflict in Europe, numerous conflicts continue to rage in the developing world. Many of these conflicts are between ill-disciplined or irregular armies who often specifically target civilian populations in defiance of the Geneva Conventions. In this process, children are inevitably susceptible to sustaining gunshot wounds.

The International Committee of the Red Cross has drawn attention to the global proliferation of weapons. For example, there are estimated to be as many as 125 million AK47 assault rifles in circulation worldwide. As conflicts resolve, these weapons become marketable commodities and spread to neighbouring states, where they become the criminal’s weapon of choice. The net result of this is injury to the civilian population, including children.

Ballistics

The science of ballistics addresses aspects of missile and bullet flight and relates these to the potential for injury. The following issues are relevant to the mechanism of wounding:

- When a bullet impacts on tissue it will impart some of its kinetic energy to that tissue.
- This will cause the tissue to accelerate away from the track of the projectile, resulting in a temporary cavity.
- Once the bullet has passed, the inherent elasticity of the tissues will cause the temporary cavity to collapse, leaving some degree of permanent cavity along the track.

The extent to which cavitation occurs is governed by the amount of kinetic energy imparted to the tissues by the projectile. The equation governing this is as follows:

$$\text{kinetic energy} = \frac{1}{2} m (V_f - V_i)^2$$

where $m$ is the mass of the projectile, $V_f$ is the velocity on entering the tissues and $V_i$ is the velocity on exiting. The degree to which the projectile’s velocity is attenuated while transiting the tissues is dependent upon the diameter of the bullet, its orientation and flight characteristics on impact, and the nature of the tissue itself.

Categories of gunshot wounds

In practice, the masses of most commonly used bullets are similar, and thus the velocity of the projectile largely defines the injury potential. In this regard, gunshot wounds can largely be divided into three categories depending on the nature of the weapon used.
Handguns
- The commonest types of handgun feature a bullet with a diameter of 9mm and a muzzle velocity of around 1000 feet/second.
- Only a small temporary cavity is formed, and the injury is essentially confined to the bullet track.
- Provided that the bullet has not transected any major structures, the degree of injury may only be slight.
- Some of the bullets for these types of weapon are designed to deform on impact. These are the hollow or soft- (lead-) tipped bullets. On impact they tend to flatten, presenting a greater surface area to the direction of travel, thus resulting in an increased transfer of energy and greater woundung effect.

Shotguns
- The cartridge contains multiple pellets of a specified diameter.
- This diameter can range from 1 mm (‘birdshot’) to 10mm (‘buckshot’).
- Once fired, the pellets disperse in a cone-shaped pattern.
- The degree and rapidity of dispersion are proportional to the size and number of pellets as well as the diameter of the shotgun barrel at the muzzle.
- Due to their aerodynamics, the velocity of individual pellets will attenuate over short distances, even in air. Furthermore, the conical dispersion leads to a rapid decline in the number of pellets that will hit a particular target as the range increases.
- The above factors lead to this weapon being virtually ineffective at ranges over 50 metres.
- A severe pattern of injury is seen at close range. Although each pellet may only be travelling at low ballistic velocity, the combined effect of multiple pellets is a formidable destructive force, shredding the tissues and causing massive disruption.

Military assault rifles
- These weapons typically have a bullet 7.62 mm in diameter that leaves the weapon at a speed of around 3000 feet/second.
- Rifling of the barrel sets the bullet spinning, which, combined with the increased velocity, leads to greater accuracy at long range.
- Rather than following a uniform flight path, the bullet has a periodic motion, oscillating around its flight axis with the movements of precession, nutation and yaw.
- The very much greater kinetic energy of these bullets leads to a much larger temporary cavity than is seen in low-velocity munitions.
- The sub-atmospheric pressure in the cavity will tend to suck in clothing and other debris from outside the wound, causing contamination.
- The shock front of accelerating tissue, propagating away from the point of impact, causes stretching and tearing of the tissues, cellular disruption and microvascular injury.
- The margin of tissue around the cavity, termed the zone of extravasation, is full of haemorrhage, has little tendency to further bleeding and, if muscle, shows no tendency to contract when stimulated. This tissue is non-viable and will become a culture medium for infection if left in situ.
- The shock wave itself can cause fracture of bone and intimal disruption of major vessels.
- The oscillating nature of the bullet trajectory can cause it to ‘tumble’ on impacting with the tissues. When this occurs, due to the non-uniform motion, even greater proportions of the kinetic energy are transmitted. The resulting tissue acceleration can lead to the exit wound made by such a bullet being very much larger than the entry wound.
- The nature of the tissue being transited has a great impact on the extent of damage occurring. Relatively elastic, compressible tissue such as lung propagates the shock wave to a much lesser extent than dense, fluid-filled tissue such as liver. Therefore a high-velocity bullet may transit lung causing only contusion, whereas transiting solid organs causes gross disruption.

Treatment
Although it is clearly impossible to cover the treatment of gunshot wounds to every possible anatomical structure in the body, there are some themes common to all such injuries. Most of the wounds encountered will be to the limbs, as gunshot wounds to the head, chest and abdomen have a high rate of on-scene mortality.

Protocols for treating gunshot wounds have been adopted and publicised by the International Committee of the Red Cross (ICRC), who have extensive experience of treating such injuries as part of their war surgery programmes.

Initial measures
The initial measures in the treatment of gunshot wounds are similar to those for any severe injury.
- General assessment and resuscitation of the patient, addressing potentially life-threatening conditions according to ABC priorities (compressing exsanguinating haemorrhage, airway, breathing, circulation), is the priority (see Section 7.3.A).
- The degree to which fluid resuscitation should be carried out has been controversial. An initial bolus of 10mL/kg in a child or 500mL in pregnancy of Ringer-lactate or Hartmann’s should be given and the response to this initial fluid challenge assessed. The concern is to avoid restarting massive bleeding again from disrupting a just-clotting wound by increasing peripheral perfusion. So until the patient can be in a position to have any torn vessels managed, i.e. be in an operating theatre with competent staff, and receive a blood transfusion, crystalloid fluid management remains the minimum that keeps vital organs perfused.
- Give analgesia as required (usually IV morphine) (see Section 1.15).
- Apply dressings to the open wounds.
- Undertake emergency splintage of fractures.
- Antibiotics: the ICRC recommend IV benzylpenicillin at a dose appropriate to the size of the child (usually 50mg/kg IV 6-hourly) and in pregnancy 600–1200mg IV 6-hourly.
- Give tetanus toxoid and antitetanus serum.
- Appropriate radiographs of the injured areas should be taken.
Wound assessment
Before proceeding to surgical treatment, the following aspects of the wound need to be assessed:
- From the history, the nature of the weapon used (if known).
- The site of the entrance wound (and exit wound, if present).
- The sizes of the entrance and exit wounds.
- Cavity formation.
- The anatomical structures that may have been transited.
- Distal perfusion.
- Presence of fractures.
- Degree of contamination.

Wound debridement and management
This involves removal from the wound of any dead and contaminated tissue which if left would become a medium for infection. It is most relevant to high-energy-transfer (high-velocity) wounds, which feature large cavities and considerable amounts of dead tissue and contamination.
- Wound debridement should be a planned procedure with prior consideration given to the position of the patient and the type of anaesthesia required.
- For limb wounds, a pneumatic tourniquet should be used where possible to reduce blood loss.
- Skin incision decompresses the wound and allows swelling of the tissues without constriction.
- Where possible, the incisions should be longitudinal and not cross joints.
- Skin is a resilient tissue, so only minimal excision is usually necessary.
- Dead and contaminated tissue should be excised.
- Dead muscle is dusky in colour, shows little tendency to bleed, and does not contract to forceps pressure.
- Foreign material should be excised from the wound. However, the obsessive pursuit of small metallic debris, such as that from a disintegrating bullet or shotgun pellets, is not worthwhile.
- Bone fragments denuded of soft-tissue attachment (muscle or periosteum) should be removed as, if left in the wound, they will become infected and form osteomyelitic sequestra.
- There should be no primary repair of nerve or tendon. Where obviously divided, these structures should be marked (with suture) for later repair.
- At the end of the procedure, the debrided wound should be washed with copious quantities of saline and then a dry bulky sterile dressing applied.
- Some low-energy-transfer (low-velocity) wounds, such as those from most handguns, because of the minimal cavitation and zone of extravasation, do not need the extensive debridement and excision outlined above. These wounds can, in certain circumstances, be managed without surgery.

Delayed primary closure
Once wound debridement has been undertaken, the patient can be returned to the ward and the following regime followed:
- Continued analgesia.
- Benzylpenicillin; IV 50 mg/kg every 4 hours for the first 24 hours and then orally for a further 4 days (12.5 mg/kg four times daily).
- Monitoring of the patient for signs of sepsis; check their tetanus status.
- The dressing should be left in place on the ward and only removed when the patient returns to theatre after an interval period for delayed primary closure.
- The ICRC recommend an interval period of 5 days, but most recent practice tends towards shorter periods of 48–72 hours.
- The only indication for return to theatre and dressing removal before this interval period has elapsed is an offensive dressing combined with signs of patient sepsis. The most common cause of this situation is an inadequate initial wound excision.

In the process of delayed primary closure:
- The dressing should be removed in theatre under appropriate anaesthesia.
- If clean, the wound can be closed, or if skin cover is deficient, split-skin grafted.
- If there is evidence of infection, further debridement/excision can be undertaken and the process repeated, aiming for delayed closure after a further 5 days.
- Following closure, rehabilitation of the injured part can commence.

Specific features relating to certain anatomical sites
- Wounds of the head and neck, by virtue of the enhanced vascular supply to these areas, can safely be closed or reconstructed at the initial operation.
- Wounds to major vessels need to be reconstructed primarily.
- Breaches of the dura, pleura and peritoneum should, where possible, be closed at initial surgery.
- Most gunshot wounds to the chest can be treated with tube thoracostomy alone.
- Penetration within 5 cm of the midline of the thorax or abdomen is associated with a risk of injury to the great vessels or heart.
- Gunshot wounds to the head that transit the cranial cavity carry a very poor prognosis, especially if from a high-energy-transfer weapon.
- Penetrating gunshot wounds of the abdomen are associated with a more than 85% chance of bowel or major organ transit. Exploratory laparotomy is therefore virtually mandatory.

Conclusion
Gunshot wounds from any type of weapon represent a severe injury. Some understanding of ballistics can help in the assessment of these injuries. Treatment according to basic principles, such as those recommended by the International Committee of the Red Cross, can lead to a satisfactory outcome even with limited clinical resources.
7.3.1.a Ingestion burns

**Box 7.3.1.A Minimum standards**

- ABCD management.
- IV steroids.
- Stomal feeding.
- Oesophageal dilation/stenting.
- Oesophageal reconstruction.

**Introduction**

Oral and oesophageal burns occur in three groups of patients: unintentional ingestion of hot or caustic liquids by young children, or by people of any age with delayed development (poor supervision plays an important part in each of these two groups), and ingestion to cause intentional self-harm.

**Types of ingestion burns**

**Hot fluids**

- Burns from drinking hot fluids are relatively rare in developmentally normal children, but can occur in those with learning difficulties.
- Normally only the mouth is burned.
- Swelling and blistering can be very rapid, and require an oral or nasal (preferred) airway.
- Swelling usually goes down within 48 hours, and the need for further treatment is unusual.

**Caustic fluids**

- Burns from drinking caustic fluids are much more severe.
- In general, caustic alkali solutions are more damaging to tissues than acids.

**Immediate treatment**

- In the home or at the place where ingestion occurred, the immediate drinking of a small amount of milk (this is futile after 30 minutes) may have some beneficial effect in the case of ingestion of solid or granular alkalis, but not for liquid alkalis or for acids.

**Hospital treatment**

- Assess Airway, Breathing and Circulation. If there are signs of developing or actual airway obstruction, call for an anaesthetist, open the airway and consider early intubation before swelling and total respiratory obstruction occur. Observe closely for shock.

- Do not pass a tube into the stomach, as this may perforate the oesophagus. A gastrostomy will usually be needed.

- Do not attempt to neutralise the chemical (e.g. by giving acid for alkali ingestion, or alkali for acid ingestion), as this will cause a high-temperature reaction that will further damage the tissues.

- Do not give more milk or give water: it is too late and may precipitate vomiting and more damage to the oesophagus.

**Definitive treatment**

- The only way to assess the oesophageal damage is by flexible oesophagoscopy. If there are significant signs of inflammation, steroids are often used, and there is some evidence that they can reduce the severity of any developing stricture. The route will have to be parenteral (hydrocortisone 4 mg/kg every 6 hours, maximum dose for children under 2 years is 25 mg, for those under 5 years is 50 mg, and for those over 5 years is 100 mg per dose). The length of treatment is not identified, but should be short (3–4 days) in view of the effect of steroids on healing and immunity.

- Significant stricture formation will need reconstructive surgery or a gastrostomy (see below).

**Complications**

- Serious burning, particularly of the oesophagus, can lead to perforation, and in the later stages to strictures.
- Acute perforation of the oesophagus is frequently fatal; treat by drip and suction and then thoracotomy if severe.
- Late stricture during and after the healing phase is a very common problem after ingestion of caustic fluids.
- Mild cases can be treated by later dilatation of the oesophagus.

- More severe cases may require an oesophagectomy, followed by a stomach pull-up or small bowel replacement.

- However, if the stricture reduces the ability of the child to eat, a feeding gastrostomy tube passed through the abdominal wall directly into the stomach may be needed to provide nutrition.

**Prevention**

- Parents and teachers must be informed about the need to keep dangerous fluids out of the reach of children.
- Never put chemicals in the wrong bottles or containers.

7.3.1.b Burns in children and in pregnancy

**Box 7.3.1.B Minimum standards**

- ABC management.
- Analgesia.
- Antiseptic dressings.
- Anti-tetanus immunisation.
- Antibiotics.

**Summary of actions (more information on each action below)**

- Primary assessment and resuscitation according to ABC. If there are signs of developing or actual airway obstruction, call for an anaesthetist, open the airway and consider early intubation before swelling and total respiratory obstruction occur. Observe closely for shock.
Introduction

The skin is a barrier to infection and evaporative fluid loss. It is a sensory organ and it regulates temperature through sweating.

- Take a very brief history, and consider whether there could be other injuries or medical conditions.
- Make a rapid assessment of the burn area, take care with clothing removal.
- If there are clearly more than 10% burns, establish an IV cannula and give IV analgesia (morphine according to age and weight see Section 1.15).
- Commence either Ringer-lactate or Hartmann’s solution IV in the following volumes in mL:

  - burn (%) × weight (kg) × 4 per day for a child
  - burn (%) × weight (kg) × 2 to 4 per day in pregnancy

- Fluid is given over the first 24 hours, backdated to the time of the burn. Half of the fluid should be given (in hourly divided doses) during the first 8 hours, and the second half in the next 16 hours, again in hourly doses. This is in addition to maintenance fluids which can be given later and orally if the child is able to take these (see below). Any fluid boluses given IV to treat shock should be included in the additional fluid for the burn and subtracted from that calculated as described above.
- Normal (0.9%) saline can be used if Ringer-lactate or Hartmann’s solution are unavailable, but be aware that, especially in larger volumes, normal saline causes a hyperchloraemic acidosis which is detrimental to sick or injured patients.
- Even if there are less than 10% burns, consider IV opiate analgesia if the patient is clearly distressed by pain.
- Do not give oral fluids immediately.
- Make an accurate assessment of the area of the burn and draw its position on a chart (see Table 7.3.I.B.1 and Figure 7.3.I.B.1).
- Estimate the depth of the burn.
- Establish, and if necessary update, the anti-tetanus status of the patient.
- Consider and decide whether an escharotomy is necessary for circumferential burns on a limb or the chest that may cause tissue necrosis from compression by swelling tissues or restriction of ventilation.
- Dress the burned areas, or treat any area that is going to be kept exposed.
- Consider and decide whether the patient needs admission (for a child, with their parent).
- Commence oral fluids if the patient can drink. If not, add the maintenance fluids to those given for the burn as calculated above. In burns over 8% divide the calculated daily maintenance requirement by 24 and give it on an hourly basis either orally or IV.
- Decide whether the patient requires urinary catheterisation (over 30% burns, or burns with complications).

Burns are more common where there is poverty from overcrowding and unsafe heating and cooking practices.

Definition of terms

Erythema or first-degree burn: This causes an increase in skin capillary blood flow. In pigmented skin it is often difficult to recognise, but is characterised by pain, and a slight thickening and change in texture of the surface of the skin with later partial or complete desquamation occurring some days afterwards. The important feature is that blistering does not occur, and fluid is not lost from the circulation. Intravenous fluids are therefore not needed for the burn. It heals without scarring within 2–10 days.

Superficial partial-thickness burn: This is skin in which there is early (within 1 hour) blistering following the injury, associated with pain. If the blisters are removed (do not remove them), the exposed surface is shiny, loses pigmentation in pigmented races, and is extremely painful. Pressure on the surface causes blanching, which on release of the pressure instantly becomes red again. It heals within 7–14 days with mild pigmentation change or scarring.

Deep dermal burn: Red blood cells leave the capillaries and become fixed in the dermis. In non-pigmented skin, therefore, the redness does not blanch on pressure. This is much more difficult to diagnose in pigmented skin, but the skin becomes thicker and harder in the area. Blistering occurs later, or may not occur at all. If the burn is in the deeper part of the dermis, the heat breaks down the red cells and the area becomes white with no blanching present. Removal of the blistering, if it has occurred, leaves a bed that is wet and shiny, but has only mild discomfort as the nerve endings have been damaged. It heals within 14–21 days with scarring which is often hypertrophic. Grafting will usually be required.

Both of the last two categories may be called a second-degree burn, but as the treatment may be different, the type that is present should be accurately diagnosed.

Deep burn: All elements of the skin and the skin hair follicles, sweat glands, etc. are destroyed. The skin is either white or charred brown. No blistering occurs. It is pointless on examination. Severe scarring occurs and grafting will always be required. This may be called a third degree burn. A burn involving tissue damage occurs at temperatures above 48°C and after only 1 second at 70°C.

Capillary permeability is increased for up to 48 hours, and is maximal at 8 hours. With large burns there is increased blood viscosity, haemoglobinuria may occur, and there is a loss of protein, which needs to be corrected by adequate nutrition.

First aid

Cold water rapidly applied is the best first aid. The quicker this is done, the better. The longer the skin is in contact with the flame or hot fluid, the greater is the extent and depth of burning. The best first aid in all situations, except those involving electricity, is cold water or other cold fluid (e.g. milk) applied as soon as possible. It is less important whether the water is sterile or not, and it should be applied before the clothes are removed, as removal can often take some time. Cold water reduces the severity of the burn as it removes thermal energy, and also reduces pain. It should ideally be applied for approximately 10 minutes,
but no longer. Following this, the burn should be covered with clean sheets or towels or ‘clingfilm’ plastic wrapping.

If the cause of the burn is electricity, it is important that the patient is isolated from the electricity supply or that it is turned off before cold water is applied, otherwise greater damage may be caused.

Following the period of cooling with water, the patient needs to be kept warm, otherwise hypothermia can result, particularly in young babies.

**Primary assessment**
- Assessment of a burn must be carried out in the same way as assessment of any other injury.
- It is quite possible that the burn is not the major injury or problem when the patient is seen. For instance, it may have been an epileptic attack that caused the burn, or the patient may have fallen or jumped from a burning house, or been involved in a road traffic accident and therefore has multiple fractures and/or a head injury.
- **Special issues regarding burns in pregnancy.** Any burn affecting more than 20% total body surface area (TBSA) is a serious risk to the mother and fetus. In a mother with a burn > 70–80% of the TBSA mortality is 50–80%. If the burn affects < 30% TBSA the prognosis is good for both fetus and mother and depends on the management of complications such as hypoxia, hypotension and sepsis.

**ABC**

*Airway and Breathing*
- If either of these is compromised, call for an anaesthetist and open the airway. Early endotracheal intubation may be required.
- If flame inhalation has occurred (see below for more information on inhalation burns), the airway tends to close very rapidly, making intubation very difficult. Apart from the history, the signs to observe are altered voice or presence of stridor, singeing of the nasal hairs, and deposition of soot in the throat or nose.
- Remove any constricting clothing and place the patient in dry and clean sheets or towels.
- Give additional inspired oxygen if SaO₂ is < 94% or the patient is cyanosed.
- If breathing is inadequate, use a bag-valve-mask and consider intubation if the airway is compromised or may imminently become so.
- Chemical damage may occur from highly irritant gases, which can lead to progressive respiratory failure.
- Many plastics and modern materials give off cyanide, which may be absorbed into the blood stream.
- Carbon monoxide is the most common poison produced in fires.

*Circulation*
- Fluid is lost through the capillaries following a burn. Shock takes time to develop. In minor burns this is a local phenomenon, but in severe burns all of the vascular bed becomes leaky. Assess the total body surface area (TBSA) affected (see below).
- A patient with a burn of less than 10% of the total body surface area can normally cope by having their oral intake increased. However, this is not an absolute figure, and in particular if the patient is vomiting, IV fluid may be necessary for a smaller burn. Similarly, if safe IV fluid is not available, a burn of up to 25% may have to be managed with increased oral fluids alone. When oral fluids are being used, either in combination with IV therapy or alone, only small regular doses of fluid should be given by mouth.
- For burns that are 5% or larger, oral fluids should be an electrolyte solution (ORS).
- Fluid loss is greatest in the first 12 hours, causing disturbances in fluid and electrolyte composition.
- For burns of 10% or more, secure IV access and replace fluids with warmed Ringer-lactate or Hartmann’s each containing 5 or 10% glucose (see below for calculating TBSA and the Appendix for how to make up solutions containing glucose).

**Management of the circulation in pregnancy**

A pregnant woman requires 2 to 4 mL per kg per 1% of body surface area burnt to be given over the first 24 hours in addition to baseline maintenance fluids. Half of this volume is given in the first 8 hours, half in the next 16 hours. The quantity of fluid given in the first 8 hours must include any fluids given as a resuscitation bolus for shock.
- Monitor urinary output (should be > 30 mL per hour).
- Assess the need to deliver the fetus. Fetal survival is poor in burns affecting > 50% TBSA. In view of the high mortality in mothers with such extensive burns, those in the second or third trimester should be delivered as soon as possible after admission as fetal survival is not improved by waiting and the presence of the fetus increases the risk to the mother. Abortion is common in patients with burns > 33% TBSA, especially during the second trimester. Fetal loss during the third trimester can be expected with extensive burns unless delivery occurs. Dexamethasone to reduce respiratory distress syndrome in a preterm infant (Section 3.1) is not contraindicated in the presence of extensive burns.

**Management of the circulation in childhood**

Children usually require 4 mL per kg per 1% body surface area burnt (TBSA) to be given over the first 24 hours in addition to baseline maintenance fluids. Half of this volume is given in the first 8 hours, half in the next 16 hours. To avoid circulatory overload, the quantity of fluid given in the first 8 hours must include any fluids given as a resuscitation bolus for shock.
- For example, if there is a 20% burn × 15 kg child × 4 = 1200 mL of Ringer-lactate or Hartmann’s solution. Give 600 mL in the first 8 hours from the time of the burn.

**Intravenous fluid management**
- IV Ringer-lactate or Hartmann’s solution or 0.9% saline (if the former two are not available) is necessary in large burns because of the loss of the intravascular component of extracellular fluid. Glucose 5% alone and glucose in 0.18% saline are dangerous and can lead to hyponatraemia and water overload. However, especially in young children, watch for hypoglycaemia, which can be prevented by adding glucose to any crystalloid solution (e.g. 50 mL of 50% glucose in a 500-mL bag of crystalloid will give a 5% solution).
- Ideally, give IV fluids by peripheral or external jugular vein; in an emergency, in shock or where rapid sequence induction for intubation is needed, intra-osseous or
central venous lines may be needed, but the latter can increase the risk of infection.

- If the patient is in shock, in a child give 10 mL/kg as an IV bolus as rapidly as possible and in pregnancy give a 500 mL IV bolus and then reassess and repeat if they are still shocked, up to a maximum of three boluses.
- Wherever possible, long IV lines should not be used, as this increases the risk of sepsicaemia.
- Both natural colloids (i.e. albumin solution and plasma) and artificial colloids (e.g. Haemaccel, and various starch derivatives) are available. The former have risks of transmitting infection and are expensive, and the latter have not been well studied for resuscitation of burns, but are cheaper.
- Blood transfusion may be needed if anaemia develops.
- It is essential that not too much IV fluid is given, as it may lead to pulmonary and/or cerebral oedema, together with an excessive extravascular deposition of fluid. Crystalloid resuscitation can also lead to ‘compartment syndrome’ because of the increasing pressure within the muscular compartments and it is important to observe for pain, particularly in the lower legs.
- The amount of fluid loss from burns decreases over the first 48–72 hours after the injury. The amount of fluid to be given initially therefore depends on how long before admission the burn occurred. Following this, the assessment of the resuscitation can be made by a combination of the clinical picture, i.e. degree of dehydration, the blood haematocrit and the urine output aim for 2 mL/kg/hour of urine in a child and 30 mL/hour in pregnancy.
- It is essential that accurate and updated fluid input and output charts are kept throughout. For major burns (over 30%), hourly haematocrit (or haemoglobin) and urine outputs are helpful in the first 24 hours, decreasing in frequency thereafter. For burns between 10% and 30%, 4-hourly tests are normally sufficient.
- In larger burns (greater than 30%), burns involving the genitals, and burns in young normally incontinent female children, a urinary catheter is essential. In males, a urinary bag can be used. A catheter may also be necessary if fluid resuscitation is not proceeding well to give an accurate picture of the urine volume produced hourly. Catheters can lead to infection and should be removed as soon as possible.

**Enteral fluid management**

- Start oral or nasogastric feeding as soon as possible after admission. If a child is being breastfeeded, this should continue.
- Although thirst is common, giving too much free fluid orally may induce vomiting.
- For burns between 5% and 10% the daily requirement of the patient’s oral intake should be increased by 50% to allow for the burn (given on an hourly basis).
- The normal oral requirement of a child can be calculated as 100 mL/kg for the first 10 kg, 50 mL/kg for the next 10 kg, and 25 mL/kg for any weight up to the total weight of the child. The normal daily fluid requirement in pregnancy is 1500–2500 mL.
- This may need to be increased by 10% or 20% in hot climates.
- The oral fluid given should ideally be ORS. If this is not available, diluted milk is acceptable.
- If all is well after 24 hours, free fluids can be given, but careful input and output charting will continue to be required.

**Maintenance of body temperature:** burnt children can lose heat rapidly.

**Feeding**

- Early feeding (especially breastfeeding) reduces the risk of gastric stress ulcer formation and of stasis. It is recommended therefore that small quantities of food are given either orally or with a thin-bore nasogastric tube. The latter can be used to give milk or other similar high-protein foodstuffs.
- Parenteral nutrition is strongly contraindicated, as this leads to a high risk of sepsicaemia in burns patients.

---

**Burn area and depth**

**TABLE 7.3.I.B.1 Body proportions at different ages for burns assessment (%)**

<table>
<thead>
<tr>
<th>Percentage surface area at:</th>
<th>0</th>
<th>1 year</th>
<th>5 years</th>
<th>10 years</th>
<th>15 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area on diagram</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>9.5</td>
<td>8.5</td>
<td>6.5</td>
<td>5.5</td>
<td>4.5</td>
</tr>
<tr>
<td>B</td>
<td>2.75</td>
<td>3.25</td>
<td>4.0</td>
<td>4.5</td>
<td>4.5</td>
</tr>
<tr>
<td>C</td>
<td>2.5</td>
<td>2.5</td>
<td>2.75</td>
<td>3.0</td>
<td>3.25</td>
</tr>
</tbody>
</table>

**Area of burn**

Estimation of the area of a burn is based on either Wallace’s rule of nines, or on charts (see Table 7.3.I.B.1 and Figures 7.3.I.B.1 and 7.3.I.B.2). In addition, the area of the patient’s open palm is approximately 1% of the total body surface area. Wallace’s rule of nines is applicable to children over 14 years of age and to adults. For newborn babies it can be modified by adding 9% to the area of the head and subtracting 9% from the area of the legs. For every additional year of age, 1% is subtracted from the head and added to the legs until, at the age of 10 years, approximately adult proportions has been reached.

In pregnancy the abdomen represents a larger proportion of the TBSA. The area of the patient’s hand can be used for estimating the size of small burns, but can also be used to estimate the areas that are unburned in extensive burns, and this can then be extracted from the rule of nines figures (e.g. if 2% of an arm is unburned, the area of burn on that arm will be 7%).

- It is very common for inexperienced people to overestimate the size of a burn.
- **Erythema must not be included**, as fluid is not lost.
- The decision as to whether or not to start IV fluids is...
dependent on this initial assessment, and on whether there are other injuries or medical conditions.

- An overestimate may mean that far too much fluid is given.

Depth of the burn

The depth of the burn is based on history, appearance and examination.

- Flame or hot fat burns are almost always deep.
- Hot water burns (scalds) may be superficial or deep dermal.
- The appearance can be altered if more than a few hours old, or by the application of various first-aid treatments.
- First assess capillary return. Prompt capillary return means a superficial burn.
- Then test sensation. Is it increased (in a superficial partial thickness burn), reduced (in a deep dermal burn) or absent (in a full-thickness burn)?
- The test is done by using a sterile hypodermic needle. In older children, and in pregnancy, it is possible to ask whether they can tell the difference between the sharp and the blunt ends when these are lightly applied to the burn. In younger children the best way of doing the test is to wait until the child is sleeping or has their eyes closed, and then very gently touch what appears to be the deepest part of the burn. If there is a sudden startle reflex, it is probably a superficial partial-thickness burn. A slow awakening indicates a deep dermal burn, and if it is possible to put the needle into the burn without any response it is likely to be a deep burn.
- In full thickness burns the area is insensitive to pain and may appear dirty or white (the eschar).
- A simple test to distinguish between partial and full thickness burns is to pull a hair out: if it comes out easily the burn is full thickness.

Many superficial burns become deeper during the first 48 hours after their occurrence, and need to be reassessed at 48 hours.

Inhalational injury

This includes:

- thermal damage
- asphyxiation
- pulmonary irritation.

Thermal damage

- This is usually limited to the oropharyngeal area.
- The exceptions are injuries caused by steam, volatile gases, explosive gases or aspiration of hot liquids.

Asphyxiation

Combustion utilises oxygen in the burning environment, leading to hypoxia. The production of carbon monoxide within the burning environment causes further tissue hypoxia by:

- decreasing the oxygen-carrying capacity of the blood
- shifting the oxyhaemoglobin saturation dissociation curve towards the left
- decreasing myocardial contractility.
The highest possible concentration of oxygen should be given.

Cyanide gas can be released during the combustion of plastics, polyurethane, wool, silk, nylon, nitrites, rubber and paper products. It is 20 times more toxic than carbon monoxide, and can cause immediate respiratory arrest.

Methaemoglobinemia occurs due to heat denaturation of haemoglobin, oxides produced in fire, and methaemoglobin-forming materials such as nitrites. Rarer than cyanide and carbon monoxide toxicity, this decreases the oxygen-carrying capacity of the blood and causes a shift of the oxyhaemoglobin dissociation curve to the left, similarly to carboxyhaemoglobin (HbCO). Again treat with high concentrations of oxygen.

Pulmonary irritation
- Direct tissue injury.
- Acute bronchospasm.
- Activation of the body’s inflammatory response system.

Evidence of inhalational injury
- Burns around the mouth.
- Soot in the mouth or nostrils.
- Carbonaceous sputum.
- Singed facial or nasal hairs.
- Facial burns.
- Oropharyngeal oedema.
- Changes in the voice (hoarseness), and stridor.
- Altered mental status.
- History suggesting confinement in a smoke-filled environment.

Symptoms may be delayed until 24–36 hours after injury. Secure the airway by endotracheal intubation before dangerous obstruction develops.

Deliver high-flow supplemental oxygen. Inhalation of hot gas normally does not injure distal airways, as the heat-exchange capacity of the upper airway is excellent. Distal airway injury is more likely to be due to the direct effects of the products of combustion on the mucosa and alveoli.

Treatment of skin surface burns

Analgesia
In all cases of shock, or potential shock, IV opiate analgesia should be given (see Section 1.15).

Oral analgesia is ineffective, and IM analgesia can be very dangerous because when the circulatory volume is re-established and muscle blood flow recommences, the child can become overdosed. Opiate overdose can be reversed with naltrexone given intravenously (see Section 1.15).

Treatment of the burn itself

Minor burns
The best definition of a minor burn is one that can be treated as an outpatient.

Hospital admission
A child with a burn should be admitted unless it is completely safe for them to be treated as an outpatient. If possible, isolate the child in a warm clean room.

The following patients require admission:
- all airway burns or patients with a history of smoke inhalation
- burns of more than 5% TBSA in children and in pregnancy
- deep burns more than 5cm in diameter
- moderate burns of the face, hands or perineum
- circumferential burns of the thorax or extremities*
- electrical burns (see Section 7.3.D)
- where there is inadequate social support in the home
- where there is any suspicion of non-accidental injury.

*If circumferential full-thickness burns involving the extremities or the chest are present, escharotomy may be necessary.

Dressings
Because a burn is normally caused by hot fluids or flame, the burn wound is initially sterile.

Hands should be washed and sterile gloves should be worn by all members of the team whenever the patient is being touched.

Ideally plastic aprons should also be used to prevent cross-infection during dressings, etc.

The purposes of a dressing are:
- to maintain sterility
- to relieve pain
- to absorb fluid produced by the burn wound
- to aid healing.

Placement of the dressing
- The layer of the dressing closest to the wound should be non-adherent (e.g. paraffin gauze) and may contain an antiseptic, such as silver sulphadiazine, although the evidence that antiseptics are useful to prevent infection and promote healing is ambiguous.
- On top of this dressing should be placed a layer of gauze and then sterile cotton wool to absorb fluid.
- The whole dressing should be held in place by a bandage.

Dressing changes
- Every time a dressing is changed, there will be pain, and the delicate reforming epithelium will be injured.
- Therefore dressings should not be changed on a daily basis. particularly in a superficial partial-thickness wound. The initial change should be at approximately 48 hours after the burn, when dressings come off easily, the maximum amount of fluid has been discharged from the wound, and it is possible to reassess the wound for area and depth.
- Effective pain relief is vital at dressing changes or the child will come to dread the procedure. Providing an anaesthetist is present, ketamine provides excellent brief anaesthesia of up to 15 minutes with an IV injection (over 1 minute) of 250–500 microgram/kg ketamine. For longer anaesthesia, an infusion will be needed. A safer alternative, especially in pregnancy, is oral morphine (see Section 1.15 for doses) given about 30 minutes before the anticipated dressing change.
- If at the first dressing change the wound is still a superficial partial-thickness burn, the second dressing is left for a further 8 days, by which stage healing should have occurred.
- If the wound is deeper, a decision as to whether to
operate must be made (see below), but the second dressing can still be left for at least a week.

- If surgery is not possible or appropriate, dressings can be done initially on a weekly basis but increased to two or three times a week as greater infection and discharge develops.

- Take a sample for microbiology (if available).

**Tetanus**

Anti-tetanus prophylaxis should be given at the earliest possible time.

---

### TABLE 7.3.I.B.2 Guide to tetanus immunoglobulin and tetanus toxoid use in wounds

<table>
<thead>
<tr>
<th>History of tetanus vaccination</th>
<th>Type of wound</th>
<th>Tetanus vaccine booster (see below)</th>
<th>Tetanus immunoglobulin</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 3 doses</td>
<td>All wounds</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>5–10 years since last dose</td>
<td>Clean minor wounds</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>All other wounds</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>&gt; 10 years since last dose</td>
<td>All wounds</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>&lt; 3 doses or uncertain</td>
<td>Clean minor wounds</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>All other wounds</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

In pregnancy, if the woman has not previously been vaccinated, give two doses of TT/Td one month apart.

### Antibiotics

- Haemolytic *Streptococcus pyogenes* and *Pseudomonas aeruginosa* are the most common serious infections.
- In most burns, *Staphylococcus aureus* is also present, but does not need treatment unless it is invasive. If it is, flucloxacillin or cloxacillin is more appropriate than penicillin.
- Antibiotics should only be given when there are signs of infection.
- *Streptococcus pyogenes* should be treated with benzyl penicillin and flucloxicillin if found on a swab or suspected clinically (e.g. lymphangitis).
- *Pseudomonas aeruginosa* can be treated with ceftriaxone, piperacillin, aztreonam, gentamicin or tobramycin.

### Surgery

The surgical treatment of burns can be divided into four time zones:

- Immediate: within hours.
- Early: within days.
- Medium term: within weeks.
- Long term: within years.

#### Immediate surgery

There are two operations which may need to be done within hours of the burn:

- **Tracheostomy:**
  - Whenever possible this operation should be avoided, as an endotracheal tube usually gives better results and less mortality (depending on available intensive care).
  - An emergency tracheostomy for a severely swollen oral, pharyngeal or laryngeal airway is a very high-risk operation if the airway has not already been secured. It is better to use a mini-tracheostomy through the cricothyroid membrane.
  - Tracheostomy has a high mortality because of infection, displacement, lung-volume loss and tube blockage.
- **Escharotomy:**
  - A deep circumferential full-thickness burn of the limb, or even occasionally the trunk, can act as a tourniquet to that area.
  - Very early release (i.e. within 2 hours) is necessary to prevent severe and irrecoverable muscle and nerve damage. This can be done without any anaesthetic because the deep burn has no sensation.
  - The incisions should not overlie superficial bone or tendons, but need to go down to the fascia.
  - For more severe burns, and in particular high-voltage electrical burns, appropriate incisions are needed to decompress the deep compartments as well.
  - Urgent decompression of deep compartments may be required in severe high-voltage electrical burns, which can damage the underlying muscle with no skin damage visible except at the entry and exit points.

#### Early surgery

- Early surgery for deep dermal and deep burns has been shown to give better functional and cosmetic results with less risk of infection than allowing the natural processes of the body to remove the dead tissue.
- However, it is a technique that is difficult to learn from books, and often requires blood transfusion. Therefore if tangential excision is to be used without previous experience, only a small area should be attempted.
- Blood loss can be very rapid.
- An experienced anaesthetist is important.

#### Medium-term surgery

When wounds are granulating, thin split-skin grafts (ideally perforated or meshed) can be taken to cover the granulating areas.

#### Late surgery

Reconstruction to release contractures, and to improve both function and appearance, is best carried out, where possible, in a specialist centre.

### Facilities and personnel

- All serious burn patients are best cared for in specialist burns units with a trained team of personnel. This includes all widespread second or third degree burns and burns significantly involving the face, hands and genitals.
For larger burns, ideally single rooms are most appropriate, and these should be kept warm at all times. It is extremely important that they are clean and that insects, etc. are controlled.

One of the most serious problems is cross-infection between patients, and adequate plastic aprons, gloves and hand-washing facilities must be available for all staff and relatives.

In the early stages of burn resuscitation, and after surgery, nursing should be on a one-to-one basis (if available).

Psychology
- There are frequently major psychological consequences to major burns. First, there is a long and often painful stay in hospital. Secondly, there is the loss of function and appearance that can result from the burn injury.
- There are often psychological consequences for the parents of a burnt child, both as a result of the guilt about allowing the accident to happen, and from having to come to terms with the often major alterations in appearance and function of their child.

Prevention
- The best solution to the problem of the burn injury is prevention.
- Use antenatal classes, posters in village halls and talks in school.

Features of burns that suggest child abuse
Burns are a common feature of child abuse and the clinician should have a high degree of awareness both of the physical appearance of inflicted burns and also of the developmental stage of the child to see if the injury is compatible with that stage.

Burns are sometimes used as a punishment in child rearing practices. Children with developmental delay are at particular risk of burns, both accidental and intentional.

Physical signs:
- Pattern burns that suggest contact with an object of a specific shape, such as an iron.
- Cigarette burns.
- Stocking, glove or circumferential burns.
- Burns to the genitals or perineum.

Introduction
The World Health Organization (WHO) definition of poisoning is the injury or destruction of cells by the inhalation, ingestion or absorption of a toxic substance. Key factors that predict the severity and outcome of poisoning are the nature, dose formulation and route of exposure of the poison, co-exposure to other poisons, the state of nutrition of the child or their fasting status, age, and pre-existing health conditions.

Mortality: Low- and middle-income countries have 91% of the world mortality from poisoning as reported by WHO in 2004. Accidental poisoning is most common in the 12–36 months age group.

Intentional overdose may be a cry for help, rather than a serious attempt at suicide. However, all children and young people who take intentional overdoses should have a full psychiatric and social assessment and always be admitted to hospital if facilities are available.

Drug abuse may be misuse of alcohol or abuse of volatile substances or more potent recreational drugs, such as ecstasy, LSD or opiates.

Deliberate poisoning of children by adults is rare. It may be associated with depressive illness or may be part of a spectrum of abuse inflicted on the child (see Section 7.6).

Clinical diagnosis and management
Symptoms and signs of poisoning
These can include:
- respiratory distress

80X 7.4.1 Minimum standards
- ABC, oxygen and glucose.
- Naloxone.
- Activated charcoal.
- Paediatric ipecacuanha.
- Wide-bore gastric tubes.
- Desferrioxamine.
- N-acetylcysteine.
- Sodium bicarbonate.
- Vitamin K.
- Exchange transfusion.
- Atropine.
- Pralidoxime.
- d-Penicillamine.
- EDTA.

7.4 Poisoning

Clinical diagnosis and management
Symptoms and signs of poisoning
These can include:
- respiratory distress