

Chapter 15: Trauma

1 Mechanism of injury

1.1 Learning objectives

By the end of this chapter you will be able to:

- Define trauma
- Define mechanism of injury and outline the different types
- Explain the kinetics associated with trauma
- Describe the mechanisms that can cause injury to the head, spine, chest, abdomen and pelvis.

1.2 Introduction

Trauma is the acute physiological and structural change (injury) that occurs in a patient's body when an external source of energy transfers to the body faster than the body's ability to sustain and dissipate it. The mechanism of injury (MOI) is defined as the physical forces that act on the body to cause damage [Pilbery, 2013]. Since human tissue, organs and systems can only withstand a limited range of physical, environmental and physiological stress, when the energy delivery to the body exceeds these limits, injury occurs. This tolerance to external energy delivery is dependent on which type of tissue(s) have been targeted, the age and physical health of the patient, and the type, magnitude and duration of the energy that has been transferred [Greaves, 2008].

Types of trauma

Trauma is generally divided into two types [NAEMT, 2014]:

- **Blunt:** Injuries that do not cause penetration of the skin by an external object. Typical mechanisms of blunt trauma include road traffic collisions (RTC) involving vehicles, pedestrians, motorcyclists etc., fall from height, serious sports injuries and blast injuries (although this mechanism often also causes penetrating trauma, the other type)
- **Penetrating:** Injuries caused by projectiles penetrating the skin. Examples include stab and gunshot wounds and blast injuries involving shrapnel and secondary projectiles.

1.3 Kinetics

Kinetics is the study of the relationship between motion and its forces.

In a road traffic collision there are three collisions. The first occurs when the vehicle a person is travelling in collides with another object. Newton's first law of motion states that a physical body will remain at steady speed and direction (i.e. velocity) or at rest until an external force acts upon it. In the case of a person driving their car, this force may be due to a collision with another car, vehicle or other object, such as a tree. During a head-on collision with a tree, for example, the vehicle stops abruptly, but the occupant inside will still be moving at the same velocity as they were prior to the collision until they come into contact with the vehicle (the second collision). The third collision occurs when the person's internal organs and tissues make contact with the body's hard surfaces, such as the skull or chest wall [NAEMT, 2014].

Newton's second law states that the force an object exerts is equal to its mass multiplied by its acceleration, or in the case of a collision, mass multiplied by the deceleration. Thus rapid decelerations, such as a car hitting an immovable object, or striking another vehicle travelling in the opposite direction at speed, for example, lead to large forces being exerted.

Newton's third law states that for every force, there is an equal and opposite force, meaning that the force applied to the tree in our head-on collision example is exerted on the vehicle too, leading to damage to the vehicle and, potentially, the occupants [Pilbery, 2013].

1.4 Energy

Energy is a measure of an object's ability to do work, or transfer energy to another object. The law of conservation states that energy cannot be destroyed, only transformed.

Energy comes in at least five forms [Greaves, 2008]:

- **Kinetic:** Related to motion, and the most common type of injury-causing energy

- Thermal: Kinetic energy of molecular motion, measured as temperature. The cause of burns
- Electrical: The flow of electrical charge. This type of energy mainly causes damage through conversion to thermal energy
- Chemical: Energy created or consumed during the alteration of electrical charge in chemical reactions. Explosions are often due to chemical reactions
- Nuclear: Energy released as a result of nuclear fission (the splitting of an atom into smaller parts, with associated energy release).

In trauma, it is usually kinetic energy that is of interest and this can be represented by the formula [NAEMT, 2014]:

$$\text{kinetic energy} = 1/2mv^2$$

where m is the mass of the object and v its velocity. From this, it is clear that it is the velocity of the object that makes the greatest difference to the amount of kinetic energy available to be transformed. Human tolerance to kinetic energy is influenced by the magnitude of the energy (the force applied) and the duration of the exposure, specifically the change in velocity. This is typically deceleration, for example a person's feet hitting the floor after a fall from height, or when a car strikes a large tree at speed. However, excessive acceleration can also cause injury, for example when a pilot is ejected from a jet aircraft [Greaves, 2008].

1.4.1 Energy transfer

The energy exchanged during trauma is the same, whether it is blunt or penetrating. Cavitation, the formation of a cavity or hollow, occurs during trauma as tissues in the body move away from the point of impact and their usual position. If this energy is dispersed over a wide area then penetration of the skin may not occur. Thanks to the elastic properties of tissues, body shape of the torso in particular often returns to its usual position, i.e. the cavitation is temporary. However, this may hide serious internal injury to organs and tissues that have had the kinetic energy of the impact transferred to them. Other denser tissues, such as bone, may remain deformed, giving clues to the presence of injury [Greaves, 2008].

In penetrating trauma, temporary cavitation also occurs, but there is also a permanent cavity

which remains once the temporary cavity has collapsed due to the elasticity of the tissues. In low-energy penetrating trauma, such as a stab wound, temporary cavitation may be minimal, but with higher energies, such as those in a gunshot, the temporary cavity can become significant in terms of injury to surrounding tissues and by generating a sub-atmospheric pressure within, causing external debris and dirt to be 'sucked in' to the wound [Greaves, 2008].

The mechanical damage that remains after trauma does not necessarily correlate to the severity of injury either. For example, a screwdriver plunged through the chest that damages the heart may leave only a small external injury, but is likely to be more serious than a gunshot wound to the patient's knee (Figure 1.1).

Penetrating projectiles do not always follow a straight path and can ricochet off internal organs and bone as the projectile decelerates. Although entrance and exit wounds are sometimes visible, determining which is which is not clinically important. Note that the absence of an exit wound means that much of the projectile's kinetic energy has been transferred to the body [NAEMT, 2014].

1.5 Mechanisms that cause injury

There are many mechanisms that can result in a host of isolated and multiple injuries to the human body. Some of the more common mechanisms and the injuries they cause to the



Figure 1.1 A close-range gunshot wound to the right knee, with a shotgun. Note the smaller entrance wound towards the bottom of the picture and the much larger exit wound.

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head, spine, thorax, abdomen and pelvis are covered in this section.

1.5.1 Head

If the head is travelling ahead of the body, such as during a headfirst fall, it is the first structure to receive the force of the impact and energy transference. The continued movement of the rest of the body results in compression, which can damage the scalp and skull. If the skull fractures, bony fractures can end up damaging the brain. The same damage can also be caused by the application of an external force, such as occurs as a result of a blow to the head during an assault [NAEMT, 2014].

The brain is soft and compressible and can move following the application of external forces. This can lead to shearing of brain tissue as well as rupture of the blood vessels surrounding the brain, leading to intracranial haemorrhage.

If a projectile penetrates the skull, the damage can be very severe as the kinetic energy is distributed within the confines of the skull. Small calibre bullets, for example, may not have enough energy to exit the skull, but instead contour around it, leading to extensive damage [NAEMT, 2014].

1.5.2 Spine

The main mechanisms that cause spinal injury can be divided into abnormal flexion, extension, rotation and compression. Extension or flexion with rotation are the main causes of injury to the cervical spine [Greaves, 2008; Pilbery, 2013; NAEMT, 2014].

Flexion

Hyperflexion injuries are typically caused by RTCs where lap-belts (rather than three-point belts) are used, direct blows to the occiput and rapid deceleration in flexed positions such as diving and contact sports like rugby. Hyperflexion on its own is uncommon in the cervical spine, since the chin abutting the chest limits flexion.

Flexion with rotation

The design of the first two cervical vertebrae allows for significant rotation. Injuries due to this mechanism are considered unstable as there is little in the way of bony or soft-tissue support. Not surprisingly, this mechanism is much more likely to produce significant cervical injury and is

often caused by lateral impact RTCs or direct trauma. Note that rotation rarely occurs in isolation.

Extension

These injuries are generally only found in cervical and lumbar regions and can be caused by hanging, striking the chin on a steering wheel during a collision or a rear impact collision where the headrest is improperly positioned [NAEMT, 2014].

Compression

Wedge fractures are the most common type of fracture of the lumbar and thoracic spine, but if a weight falls on the head or if the patient lands on their head after a fall, then the cervical vertebrae can be fractured and/or ligaments ruptured. Most fractures caused by compression are stable, but spinal cord injury can occur if the vertebral body is shattered and fragments of bone become embedded in the cord [Pilbery, 2013].

1.5.3 Thorax

Severe blunt thoracic trauma most commonly occurs as a result of RTCs (about 70–80%) where high speeds are involved, leading to rapid deceleration. This causes shearing forces that can rupture large blood vessels, tear the bronchial airways and damage the lungs, causing pneumothoraces, for example. Even with lower velocity mechanisms, such as direct blows to the chest, fractures of the rib cage and sternum as well as bruising to the underlying structures including the heart and lungs can occur [NAEMT, 2014].

In penetrating trauma, the most serious consequences arise as a result of rupture of the major blood vessels, which can lead to serious haemorrhage. Projectiles penetrating the chest wall can also cause open pneumothoraces [Greaves, 2008].

1.5.4 Abdomen

Abdominal injury is most commonly caused by blunt trauma, usually due to RTCs, and often as part of a multi-system pattern of injuries. If the abdomen comes into contact with the steering wheel during rapid deceleration, crush injuries can occur. Compression of the abdominal organs increases the intra-abdominal pressure, which in

turn can rupture the hollow organs and/or the diaphragm. Penetrating trauma is less common, and in the UK is more likely to be as a result of a stab wound than gunshot. Fortunately, less than half of all stab wounds actually penetrate the peritoneum (the lining of the abdominal cavity) [Greaves, 2008].

1.5.5 Pelvis

As with any trauma patient, you should consider the MOI to provide an indication as to possible underlying injuries. Pelvic ring fractures usually require high forces, so it is no surprise that the most common cause is RTCs. Front-seat passengers in head-on collisions, and those on the side of impact in T-bone type collisions in cars, are most common. These are closely followed by motorcyclists, pedestrians and falls from heights [Gabbe, 2011; Papadopoulos, 2006]. However, a significant sub-group are the elderly, who will typically fall from standing and may have osteoporosis [Garlapati, 2012].

Figure 1.2 shows three main types of pelvic ring fracture (there is an additional type, which is just a combination of the other three) and the direction of forces required to cause them [Burgess, 1990]:

- **Lateral compression (LC) fractures:** These are the most common type of pelvic ring fracture and are caused by internal rotation of the pelvic ring due to a direct force applied to the iliac crests, or indirectly via the femoral head [Garlapati, 2012]. These forces typically result in pubic rami fractures on one or both sides anteriorly, which places severe strain on the sacroiliac joints. If these become displaced, the pelvis will be unstable. The typical mechanism of injury is a side-impact RTC or fall from height.
- **Anterior–posterior compression (APC) fractures:** These are most commonly caused by a frontal collision between a pedestrian and a vehicle, front-seat passengers in a frontal RTC and crush injury [NAEMT, 2014]. With these mechanisms, either the pubic rami are fractured or the symphysis pubis is disrupted, resulting in the pelvic bones springing apart and externally rotating. This is often called an ‘open book’ injury. Posteriorly, the sacroiliac ligaments can be torn and/or the posterior

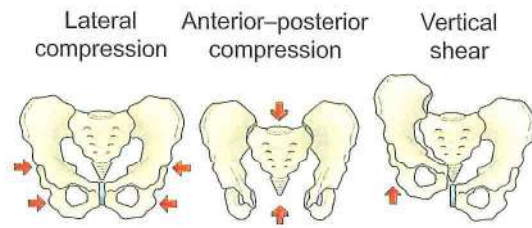


Figure 1.2 Types of pelvic fracture. The red arrows indicate the direction of the forces

aspect of the pelvic bones fractured [McCormack, 2010].

- **Vertical shear (VS) fractures:** These are the least common type of injury, but are the most likely to kill your patient [NAEMT, 2014]. These fractures occur when one of the pelvic bones is displaced vertically, leading to a fracture of the pubic rami and disruption of the sacroiliac joint on the same side. These are typically caused by falls from height, with the patient landing on one leg first. Because of this, blood vessels are often torn, leading to severe retroperitoneal haemorrhage (which can easily accommodate the body's entire blood volume [Luke, 2010]) and severe damage to soft tissues.
- **Combined mechanical (CM) fractures:** These are a combination of other types of fractures, typically caused by a multitude of forces applied in different directions, for example during a rollover RTC.

1.5.6 Blast injury

Blasts (or explosions) cause complex multi-system injury due to the significant transfer of kinetic,



Figure 1.3 An explosion, with a visible blast wave

heat and other energies. Injuries are generally classified into the five types shown in Table 1.1 [NAEMT, 2014; AACE, 2013].

2 Integumentary system anatomy and physiology

2.1 Learning objectives

By the end of this lesson you will be able to:

- Describe the anatomy and physiology of the integumentary system.

2.2 Introduction

The integumentary system (or skin) is the largest organ in the human body, in terms of both surface area and weight. In adults, skin has a surface area of 2 m² and weighs 5 kg [Tortora, 2008]. It is composed of two main layers, the epidermis and dermis. Under the skin is a supportive subcutaneous layer, known as the hypodermis or superficial fascia (Figure 2.1) [Dykes, 2002].

2.3 Epidermis

This is the outermost layer and consists of five sublayers. Most of the cells (90%) are

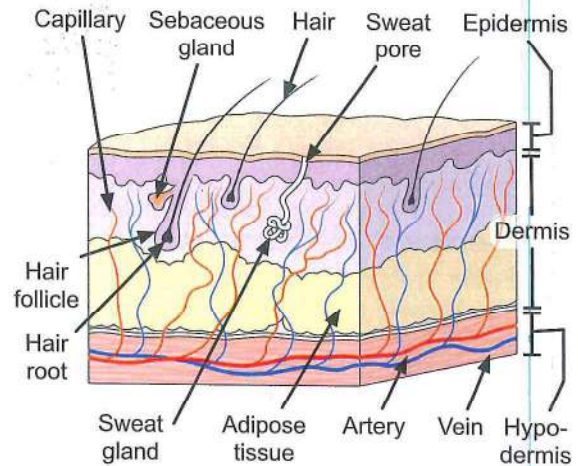


Figure 2.1 Cross-section of the skin

keratinocytes, which produce a tough, fibrous protein (keratin). This helps protect the skin and tissues from heat and microbes. Keratinocytes also produce lamellar granules which decrease water entry and loss, and prevent entry of foreign material. Around 8% of the cells are melanocytes, which produce melanin. This is taken up by keratinocytes, protecting the cell's

Table 1.1: Blast injury categories

Category	Cause	Possible injuries
Primary	Injuries caused by patient contact with blast shock wave (Figure 1.3)	Gas-containing organs may be damaged, including lungs, gastrointestinal tract
Secondary	Injuries due to flying fragments and debris striking the patient	Entire body can be affected, leading to lacerations and fractures Penetrating injuries
Tertiary	Blast wave propels patient against objects Crush injuries secondary to structural damage and building collapse	Blunt and crush injuries
Quaternary	Other explosion-related injuries and illnesses	Burns Toxic gas and exposure to other chemicals
Quinary	Injuries resulting from additives, for example bacteria and radiation ('dirty bombs')	

nucleus from the harmful effects of ultraviolet (UV) light. Keratin is either a yellow-red or brown-black pigment and contributes to skin colour. The remaining cells consist of Langerhans cells, which help in the body's immune response, and Merkel cells, which are involved in touch perception [Tortora, 2008].

It takes around 2–3 weeks for a cell starting at the lowest layer of the epidermis to become a keratinocyte and migrate up to the top layer (stratum corneum) and slough off [AAOS, 2011].

2.4 Dermis

This deeper layer of skin mostly consists of connective tissue, elastin and an extracellular matrix, which provides strength and pliability. However, it also contains blood and lymphatic vessels, nerve fibres, hair follicles and sebaceous and sweat glands. The dermis is divided into two regions, the papillary and the reticular. The papillary region consists of connective tissue that anchors the epidermis and a dense network of capillaries and small blood vessels, in nipple-like projections called dermal papillae. These play an important part in temperature regulation. In addition, the dermal papillae also contain free nerve endings, which act as pain and fine touch receptors (Meissner corpuscles) [Tortora, 2008]. The reticular region makes up 80% of the dermis and consists of dense, irregular connective tissue. Interlocking collagen fibres run in various planes, forming 'lines of cleavage'. Surgeons try to make incisions parallel to these lines, since the skin does not gape as much, resulting in less scarring [Thompson, 2008].

2.5 Hypodermis

Also known as the superficial fascia, this layer contains subcutaneous fat, connective tissue, sweat glands, muscle and bone. It helps to insulate the body, absorbs shocks to the skeletal system and enables the skin to move easily over underlying structures [AAOS, 2011].

2.6 Physiology

The skin provides a range of functions, which any damage can impair [Tortora, 2008; Thompson, 2008]:

- Protection against infection by forming a physical barrier to microbes and foreign material
- Sensory perception of pain, pressure, heat and cold
- Thermoregulation using nerves, blood vessels and sweat glands to control body temperature
- Excretion of trace amounts of water and body waste, while helping to prevent dehydration
- Maintenance of mineralisation of bones and teeth and synthesis of vitamin D
- Absorption of lipid-soluble substances such as fat-soluble vitamins and drugs through the skin.

3 Wounds and bleeding

3.1 Learning objectives

By the end of this lesson you will be able to:

- Describe the types of bleeding
- Explain how to appropriately assess and manage bleeding
- Explain how to detect concealed bleeding
- Describe various types of wounds and how to manage them
- Discuss the implications of foreign objects in wounds
- Explain complications associated with bleeding and wounds.

3.2 Introduction

Wounds and bleeding are a common reason for an ambulance to be requested. Even in the emergency ambulance service, these calls will vary in their severity, from wounds and bleeding that require basic first aid only, through to life-threatening wounds and bleeding that require prompt and more advanced intervention in order to prevent death.

3.3 Bleeding

Bleeding is the loss of blood from a damaged blood vessel. You will often hear the term 'haemorrhage' used, which is bleeding, but in medical circles is usually reserved for severe bleeding. Bleeding is often classified by the type of vessel involved (i.e. artery, vein or capillary) or whether it is external or internal [SJA, SAA, BRC, 2014].

3.3.1 Assessment

Sources of bleeding

Bleeding can be defined by whether it is visible on the outside of the body and/or which type of vessel is responsible [Gregory, 2010a; SJA, SAA, BRC, 2014]:

- **Internal:** This bleeding is concealed within the body and can be hard to detect [Greaves, 2008]. The thorax, abdomen, pelvis and long bones provide good hiding places for significant volumes of blood. The mechanism of injury and the presence of shock without signs of external haemorrhage can help with diagnosis. These patients need to be in hospital to stop the bleeding
- **External:** This bleeding is visible and should be detected during your primary and/or secondary survey. This bleeding can usually be controlled
- **Arterial:** Blood inside the arteries is under relatively high pressure and so bleeding can lead to significant blood loss. It is characterised by bright red (oxygenated) spurting, in time with the heart beat
- **Venous:** Since veins carry blood back to the heart, they typically carry deoxygenated blood and so bleeding is a darker red. Since the pressure is lower, blood does not spurt but flows freely. However, blood loss can still be severe, particularly from veins in the neck and legs
- **Capillary:** These are the smallest blood vessels in the body and carry a mixture of oxygenated and deoxygenated blood, so the colour of bleeding will vary. Blood loss tends to be small as blood oozes from wounds.

Estimating blood loss

Estimating blood loss accurately is very difficult and ambulance staff (and doctors/nurses/midwives) generally do not do this well [Frank, 2010; Bose, 2006; Tall, 2003; Moscati, 1999]. Table 3.1 provides examples of what various volumes of blood loss look like (this was originally designed for estimating obstetric blood loss) [Bose, 2006]. Fractures can cause significant blood loss, depending on the bone(s) affected and whether the fracture is open or closed (Table 3.2) [NAEMT, 2014]. Remember to check for signs and symptoms of shock (this was covered in the COMMON CARDIOVASCULAR CONDITIONS lesson in chapter 11, CIRCULATION).

3.3.2 Management

The mnemonic ABC has been in use for many years, identifying the patient management priorities in the primary survey. However, in the military, there has been a change of priorities, to include early control of catastrophic haemorrhage (<C>) before the airway, when both cannot be managed simultaneously [Hodgetts, 2006].

Once the scene assessment has been completed, you need to check for, and manage, any actual or potential catastrophic haemorrhage. Only once this has been completed can you return to the normal AcBC (i.e. airway with consideration of the cervical spine, breathing and circulation) approach.

During the assessment of circulation (the second C), any interventions to manage catastrophic haemorrhage must be reassessed to ensure that bleeding is being controlled appropriately. Don't forget the bleeding you cannot see. 'Blood on the floor plus four more' is a good way to remember the areas where significant blood loss can accumulate, i.e. the thorax, abdomen, pelvis and long bones [Greaves, 2010].

Most external haemorrhage can be controlled with simple first aid measures such as direct pressure and elevation of the bleeding extremity. In some cases, additional interventions are required, but these should be introduced in an incremental fashion, as shown in the haemostasis escalator (Figure 3.1) [Lee, 2007b; Moorhouse, 2007].

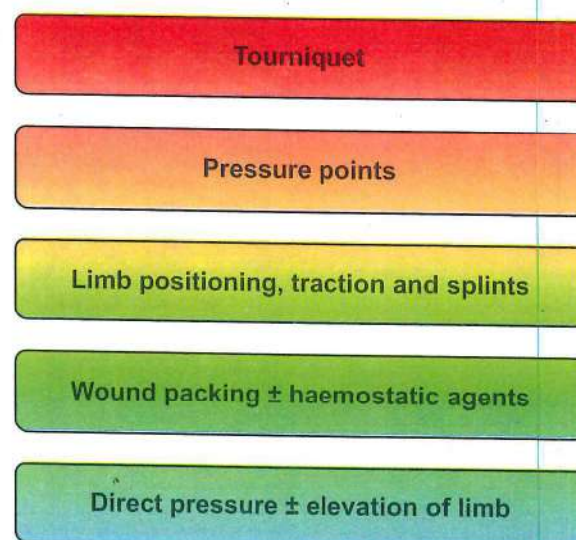
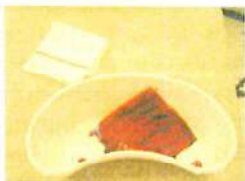
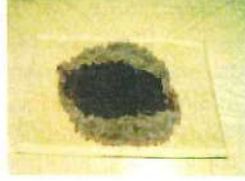


Figure 3.1 The haemostasis escalator

Table 3.1: Visual guide to estimating blood loss

Blood loss (ml)	
30	
60	
100	
250	
500	
1000	

1500

**Table 3.2: Approximate internal blood loss due to fractures**

Fracture	Blood loss (ml)
Rib	125
Radius or ulna	250–500
Humerus	500–750
Tibia	500–1000
Femur	1000–2000
Pelvis	1000–5000

If direct pressure and elevation fails to stem the bleeding, then wound packing should be undertaken and may be supplemented with haemostatic agents. This is achieved by inserting a sufficient quantity of gauze into the wound, to create mechanical pressure on the injured vessel and provide a structure for coagulation.

If this fails, assess limb positioning and consider whether the use of splinting may help reduce bleeding. Careful handling and the splinting of fractures will help in controlling haemorrhage. If this is still not sufficient, consider using pressure points to indirectly reduce distal blood flow. This involves compressing a proximal artery against a bone. Compression of the artery in this way may help reduce blood flow to the bleeding point, but still allow some degree of circulation to reach the distal tissues.

If indirect pressure fails to stem the haemorrhage, then a tourniquet should be applied.

3.3.3 Tourniquets

The use of tourniquets (Figure 3.2) has caused controversy, but they do have a place in civilian ambulance services for use in specific circumstances [Lee, 2007b]:

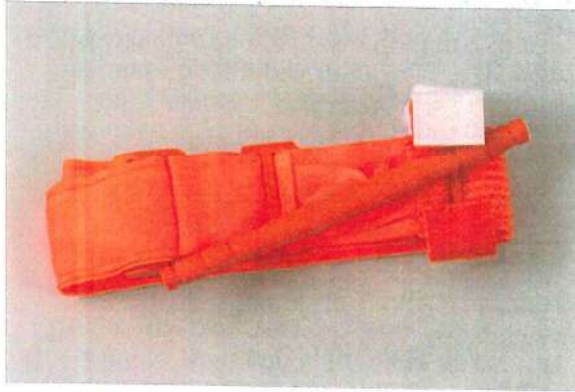


Figure 3.2 A tourniquet

- Extreme life-threatening limb haemorrhage, or limb amputation/mangled limb with multiple bleeding points, to allow immediate management of airway and breathing problems. Following treatment of any airway or breathing problems, the need for a tourniquet can be reassessed in the circulatory assessment and may be converted to a simple method of haemorrhage control
- Life-threatening limb haemorrhage not controlled by simple methods
- Point of significant haemorrhage from limb is not peripherally accessible due to entrapment (and therefore it is not possible to initiate simple methods of haemorrhage control such as direct pressure)
- Major incident or multiple casualties with extremity haemorrhage and lack of resources to maintain simple methods of haemorrhage control.

However, incorrectly applied tourniquets can actually increase blood loss if venous, but not arterial, vessels are occluded. Correctly applied tourniquets, used when not clinically indicated, can cause local tissue injury from direct contact with the tourniquet, and, when left in place for more than 2 hours, can lead to muscle and skin damage. In addition, tourniquets cause severe pain and patients must receive adequate analgesia.

Having identified a need for a tourniquet, it needs to be applied correctly. To maximise the limb and tissue perfusion, it needs to be placed as close to the injury as possible, although there does need to be a gap of at least 5 cm between the injury and tourniquet. The exceptions to this

are injuries close to the knee and elbow joints, which will necessitate the application of the tourniquet above the injury and joint.

Tourniquets applied below the knee and elbow joints may not be successful in controlling haemorrhage, as the arteries can run or slip between the tibia/fibula and radius/ulna and thus not be compressed by the tourniquet. In these cases a second tourniquet should be applied to the femur or humerus, as close to the joint as possible. The distal tourniquet can then be released. If only one tourniquet is available, consider reapplying it on the femur or humerus.

Even if the tourniquet is placed on a single long bone, the wound may still seep blood if the bone end is open, since the nutrient artery supplying the bone may be proximal to the tourniquet. However, the haemorrhage from the end of the bone is usually controllable by direct pressure.

Once a tourniquet has been applied, it should be reassessed to ensure it is still effective and required. If direct pressure and a dressing were applied after the application of a tourniquet, a trial without tourniquet should be attempted. If there is no further bleeding, the tourniquet can be left undone, but it should not be removed in case bleeding reoccurs. It also serves as a visual reminder that a tourniquet has been used. If severe bleeding occurs on loosening the tourniquet, then it should be fully reapplied and left in situ. It is important that the time of application of any tourniquet is documented and verbally handed over to the hospital staff.

3.3.4 Haemostatic agents

Where direct pressure and wound packing are ineffective, and in areas such as the groin, neck and axilla, where tourniquet application is not possible, haemostatic agents can be used to control haemorrhage [Greaves, 2008; Cox, 2009; Rossaint, 2010]. Haemostatic agents usually come in the form of granules and may additionally be impregnated into a dressing. They work by either concentrating clotting factors or acting as a precursor to coagulation, or are mucoadhesive [Granville-Chapman, 2011]. In pre-hospital medicine, the most common agents in use are QuikClot® and Celox® (Figure 3.3).



Figure 3.3 Haemostatic dressings

Celox® is extensively used within UK military practice and is a complex polysaccharide made from shellfish. The active element is chitosan, which acts as a mucoadhesive around bleeding vessels. It has been suggested that this haemostatic agent is preferable in severe trauma, as it does not rely on clotting factors to work. In severe haemorrhage, clotting factors may be in short supply due to direct blood loss and haemodilution following fluid therapy [Granville-Chapman, 2011].

Haemostatic agents are placed into the wound, as close to the bleeding point as possible. Direct pressure must then be applied to the wound site for at least 3 minutes to ensure adhesion and stable clot formation. Ideally, constant pressure should be maintained after this time with a suitable elastic bandage.

3.4 Wounds

A wound is an injury to living tissue, breaking its continuity. There are seven basic categories [Dougherty, 2011; Gregory, 2010b; Pilbery, 2013]:

- Contusion (bruises): Caused by bleeding from damaged blood vessels under the skin. They cause a bluish/purple discolouration beneath the skin and are typically caused by blunt trauma
- Abrasion (grazes): Injuries caused by friction shearing the skin away. These usually involve the superficial layers of the skin, but can go much deeper. They can be very painful and are often dirty, with embedded grit and mud
- Laceration (tear): Tearing or splitting of the skin due to blunt trauma. These cause a ragged wound, which can extend through the skin surface to the underlying structures
- Incision (cut): A break in the continuity of the skin by a sharp implement, such as broken glass or a knife. These are usually clean wounds (unless the implement is dirty) with neat edges
- Puncture (stab): A penetrating wound caused by an object that is pointed and narrow, such as a nail or knife. Although these wounds are typically small, they can be deep, causing serious damage to vessels and other body structures below the skin
- Burn: An injury caused by energy transfer to the body's tissues, causing necrosis and an associated inflammatory reaction (covered in the BURNS lesson later in this chapter)
- Gunshot: A complicated wound caused by a projectile moving at speed. The wound consists of an entry point, with varying amounts of tissue destruction and cavitation underneath the skin, and, if there is sufficient energy left, an exit wound

There are a range of external and internal factors that can lead to wound formation [Thompson, 2008]:

- External: Mechanical (friction), chemical, electrical, temperature extremes, radiation and microorganisms
- Internal: Circulatory system failure, endocrine (e.g. diabetes), neuropathy, haematological, malignancy (cancer).

3.4.1 Management

Wound management will be determined by the size and nature of the wound and the presence of complicating factors. The main initial problems are bleeding, pain and the risk of infection [Purcell, 2010]. Always enquire about tetanus immunisation in any patient who has a wound with a higher risk of infection, such as a dirty wound, or a wound caused by a bite (human or animal) or involving a puncture by a dirty object [SJA, SAA, BRC, 2014].

If the wound is small and bleeding easily controlled, clean the wound, if dirty, before placing a sterile, non-adherent dressing over the site. If the wound is suitable for treatment at

home, or at a minor injuries unit, the clinician may advise that a wet dressing be applied over the wound, although this is typically reserved for wounds where treatment will commence promptly (for example within 30–90 minutes) [Pilbery, 2013].

If there is a foreign object in the wound, it may be possible to remove it, if it's small (e.g. grit), by irrigating the wound with water, or using tweezers. However, larger objects or those which appear firmly embedded should not be removed but left in place, and a sterile, non-adherent dressing applied. These objects do need to be removed as they may lead to infection, so follow local guidance and your clinician as to the next step in the patient's management [Purcell, 2010].

4 Assessment and management of the trauma patient

4.1 Learning objectives

By the end of this lesson you will be able to:

- Explain the assessment and management of patients with a range of traumatic injuries
- Describe the complications associated with a range of traumatic injuries.

4.2 Introduction

The approach to the trauma patient is similar to that of all patients, with an initial scene assessment, followed by a primary and secondary survey. However, there are some aspects of this process that are specific to trauma and they are going to be covered in this lesson. In addition, there are a range of complications that can arise as a result of traumatic injury to specific regions and a number of these are going to be covered in this lesson, specifically injuries to the head, spine, thorax, abdomen and pelvis.

4.3 Scene assessment

The SCENE mnemonic that was reviewed in the SCENE ASSESSMENT AND SAFETY lesson (chapter 7) can be used to ensure that you cover all aspects of an initial trauma scene assessment [AACE, 2013]:

- **S: Safety.** A dynamic risk assessment should highlight current as well as potential dangers. If you are not equipped in terms of kit and expertise to deal with the scene, withdraw and request specialist help, for example from the hazardous area response team (HART). Remember to continually reassess safety as the situation can change quickly. Make sure you are wearing appropriate personal protective equipment (PPE)
- **C: Cause,** including mechanism of injury (MOI). Finding out what happened is important in order to appreciate likely injuries and energy transfer. However, ensure that the scene matches the story you are being told, as you may have come across a crime scene or case of abuse
- **E: Environment.** Consider whether there are any environmental factors that need to be taken into account. These may complicate your extrication by affecting access to and from the scene and/or increase the risk of harm to the patient, due to increased risk of hypothermia, for example
- **N: Number of patients.** Determine the number of patients early on in your assessment to help you determine whether you can manage the scene on your own. It may also help to identify patients who have either wandered off from scene or who have been ejected from a vehicle, for example, and are currently hidden from view
- **E: Extra resources needed.** Depending on the number of patients, the severity of their injuries and the nature of the incident, you may need additional help from other emergency services, such as the police to keep a scene safe, or additional ambulances, including the air ambulance, for patient transport.

4.4 Primary survey

The aim of the primary survey is to identify threats to life promptly and intervene as soon as they are found. The steps of the primary survey should be undertaken sequentially, unless there are enough personnel to allow for simultaneous assessment and treatment [Greaves, 2008].

Procedure

Take the following steps to undertake a primary survey in the trauma patient:

1. **General impression:** As you approach the patient, perform a global assessment. Are they sitting up and watching you approach, with well-perfused skin, or are they lying unresponsive, pale and clammy with an expanding pool of blood leaking from a wound?
2. **Catastrophic haemorrhage:** This is bleeding that is likely to cause death within minutes, so cannot wait until airway and breathing have been addressed. Typically, bleeding can be controlled with direct pressure and elevation of the bleeding site, but may require the use of haemostatic dressings or tourniquets (see the lesson on WOUNDS AND BLEEDING above)
3. **Airway with cervical spine consideration:** If a patient has suffered significant blunt trauma or the MOI suggests that the cervical spine may have been damaged, provide prompt manual in-line stabilisation. Assess the airway by looking for obvious obstruction, listening for noisy airflow (snoring or gurgling) and feeling for air movement.
4. Manage the airway using appropriate airway manoeuvres, such as:
 - Jaw thrust–chin lift
 - Suction
 - Naso- and oropharyngeal airways.
5. **Breathing:** Administer high-flow oxygen to patients to obtain a target saturation of 94–98%, even if they have COPD.
6. Examine the neck for:
 - Tracheal deviation
 - Wounds and swellings
 - Emphysema (surgical/subcutaneous)
 - Laryngeal crepitus
 - Veins.
7. If you have enough personnel, a cervical collar can be applied, if appropriate, once this has been completed
8. Look for obvious chest injuries, wounds, bruising or flail segments. Assess the rate, depth and quality of respiration:
 - Ventilate with a BVM if respirations absent or less than 10 breaths/min
 - If respirations are greater than 30 breaths/min it may also be clinically appropriate to ventilate the patient. Follow the advice of the clinician
 - If respirations 10–30 breaths/min monitor closely.
9. Listen (auscultate) over both axilla for air entry. If bilateral air entry is not heard, the clinician may use percussion to indicate the underlying problem
10. Feel for equality of chest movement and note any instability
11. **Note:** This assessment should include examination of the back of the chest, although it may not be appropriate to log roll the patient to do this. If the patient is supine, feel as much of the back as you can without excessively moving the patient
12. Manage breathing problems as you find them. This may include:
 - Applying non-occlusive dressings to sucking chest wounds
 - Insertion of a cannula into the chest by a clinician to decompress a tension pneumothorax
 - Positioning to support a patient with a flail segment (not possible if the patient has a suspected spinal injury).
13. **Circulation:** If a catastrophic haemorrhage was encountered at the start of the primary survey, reassess this now.
14. Assess both central and distal pulses (carotid and radial, typically), noting rate, rhythm and volume. Note the skin colour, temperature and the presence of clamminess. If additional personnel are available, the blood pressure can also be measured
15. Assess for signs of blood loss, remembering the phrase 'blood on the floor plus four more':
 - Externally: Don't forget to consider bleeding into clothing, splints and dressings
 - Chest: Completed during assessment of breathing
 - Abdomen: Look for bruising or external marks and feel for rigidity and to elicit tenderness
 - Pelvis: This should not be manipulated or 'sprung' to assess for instability. The MOI is sufficient to immobilise the pelvis
 - Long bones: Assess long bones, particularly the femurs, but do not be distracted by fractures at this stage
16. Manage bleeding appropriately (see lesson on WOUNDS AND BLEEDING above). Ideally splint pelvic fractures prior to moving the patient. Limb fractures can wait until you are en route if the patient is critically injured.

Procedure continued →

17. The clinician may wish to gain intravenous access now if fluids and/or tranexamic acid are required
 18. To minimise clot disruption, patient movement should be kept to a minimum. Use an orthopaedic (scoop) stretcher where possible.
 19. **Disability:** Calculate the Glasgow Coma Scale (GCS) score for the pre-hospital major trauma triage tool. Assess pupil size, equality and reaction to light. Don't forget to check the blood glucose.
 20. **Exposure/environment:** To identify all injuries, it is necessary to remove the patient's clothing. In cases of severe injury or suspected spinal injury, clothes should be cut off the patient to minimise movement. Take care to prevent hypothermia as this can dramatically increase their chances of dying (up to 3 times higher if core body temperature drops below 35°C [Ireland, 2011]). It may be more appropriate to remove patients to a heated ambulance before completing this step.
4. Reassess for signs of life-threatening injury, indicated by:
 - **T**racheal deviation
 - **W**ounds and swellings
 - **E**mphysema (surgical/subcutaneous)
 - **L**aryngeal crepitus
 - **V**eins
 5. **Chest:** Repeat the assessment carried out in the primary survey. Look for obvious chest injuries, wounds, bruising or flail segments. Note the presence of seat-belt marks
 6. Assess the rate, depth and quality of respiration:
 - Ventilate with a BVM if respirations absent or less than 10 breaths/min
 - If respirations greater than 30 breaths/min it may also be clinically appropriate to ventilate the patient. Follow the advice of the clinician
 - If respirations 10–30 breaths/min monitor closely
 7. Listen (auscultate) over as much of the chest (front and back) as possible. If bilateral air entry is not heard, the clinician may use percussion to indicate the underlying problem
 8. Feel for equality of chest movement and note any instability

4.5 Secondary survey

The secondary survey should only commence once all life-threatening injuries identified in the primary survey have been addressed and, in the case of severely injured patients, once they are on the way to hospital [NAEMT, 2014; AACE, 2013; Greaves, 2008].

Procedure

Take the following steps to perform a secondary survey in the trauma patient:

1. **Vital signs and history:** Obtain a full set of observations, a history of the injury-inducing event and a brief medical history (e.g. SAMPLE)
2. **Head**
 - Reassess the airway to ensure patency and check the mouth for bleeding, lacerations and loose teeth
 - Look at and feel the entire head and face to identify lacerations, bruising, fractures and burns
 - Re-check the pupils and GCS
 - Inspect the nose and ears for the presence of blood and cerebrospinal fluid (CSF) leakage as this may suggest a basal skull fracture. Other signs, such as bilateral bruising around the eyes or behind the ears, can take 12–36 hours to appear
3. **Neck:** To examine the neck properly, it is necessary to remove a cervical collar. Manual in-line stabilisation will need to be maintained while this occurs. The clinician may examine the spinous processes of the cervical spine and, depending on the result, elect to discontinue cervical spine immobilisation
9. **Abdomen**
 - Look for open wounds, bruising and seat-belt marks. Try to view as much of the front and back as possible
 - Feel the whole abdomen for tenderness, guarding and rigidity
10. **Pelvis**
 - Check for blood loss from the urethra or vagina
 - Note the presence of bruising around the perineum and scrotum (in males)
 - Discourage urination
11. **Extremities:** Thoroughly examine the lower and then upper limbs. Look for wounds and fractures. Check motor, sensory and circulatory (MSC) function in all four limbs:
 - **Motor:** Ask the patient to move the limb
 - **Sensory:** Apply light touch to evaluate sensation
 - **Circulation:** Assess a distal pulse and skin temperature.

4.6 Head injuries

Common causes of traumatic brain injury (TBI) include road traffic collisions, direct blows to the head, falls from heights and sports-related injuries. The worst outcomes are associated with [Moppett, 2007]:

- Penetrating injuries
- Non-accidental injury in children aged under 5 years
- Pedestrians and pedal cyclists
- Ejection from a vehicle.

Other clues at scene include a 'bulls-eye' pattern on a vehicle windscreen and significant damage to protective helmets, if a patient was wearing one at the time of the injury [AACE, 2013].

Once a primary brain injury has occurred, it cannot be undone. Fortunately, good pre-hospital management can help minimise the impact of secondary brain injury. It can be broken down into 3 areas:

- Recognise the injury that will indicate that a traumatic brain injury may be present
- Understand the pathophysiology relating to traumatic brain injury
- Manage the patient appropriately.

4.6.1 Recognition

Suggestive signs and symptoms of TBI include [Pante, 2010]:

- Lacerations, contusions or haematomas to the scalp
- Boggy areas when palpating the scalp
- Visible fractures or deformity of the skull
- Battle's sign or 'panda eyes' (not apparent for several hours)
- Cerebrospinal fluid and/or blood leaking from the nose or ears
- Cushing's Triad: Rising blood pressure, reducing heart rate and irregular respirations
- Dizziness
- Nausea and vomiting
- Abnormal pupils and/or pupil reaction
- Visual disturbances (double or blurred vision, seeing 'stars')
- Severe headache
- Altered level of consciousness

- Perseveration (repeatedly asking the same questions)
- Amnesia
- Paraesthesia/paralysis of the extremities
- Convulsions
- Posturing
- Abnormal respirations.

4.6.2 Pathophysiology

In the traumatically injured brain, autoregulation starts to fail and affected areas of the brain become pressure passive, relying on higher than normal mean arterial pressures to maintain cerebral blood flow.

If cerebral oedema or haematoma develops, CSF is displaced and the level of venous blood in the cranium is reduced. In the early stages of rising intracranial pressure (ICP), blood pressure will be fairly stable. However, in the later stages when the cardiovascular centre in the medulla becomes ischaemic, the Cushing reflex is triggered, resulting in peripheral vasoconstriction and a rise in blood pressure. This in turn leads to a reflex bradycardia. Respiration is also affected, leading to irregular respirations [Moppett, 2007].

4.6.3 Management

The mainstay of management for patients with TBI is preventing hypoxia, treating hypotension and transporting patients quickly to definitive care. There is a link between head injury and injury of the cervical spine, so an assumption of spinal injury should be made, unless your clinician is confident at clearing the patient's cervical spine on scene [NICE, 2014]. Cervical collars can raise ICP, but little can be done to reduce this in the pre-hospital environment [Hammell, 2009].

Airway compromise is common after severe TBI and needs to be managed. Watch for any vagal stimulation such as suction and laryngoscopy as they will increase intracranial pressure. A single drop in the patient's oxygen saturations under 90% doubles their chance of dying. Provide 100% oxygen via a non-rebreathe mask and aim for oxygen saturations of 94–98% [AACE, 2013]. Continuous monitoring of oxygen saturations is important. Assess adequacy of ventilation and provide assistance if required. If you are able to monitor EtCO₂, aim for normocapnia, as both

hypocapnia and hypercapnia have been shown to increase mortality [Hammell, 2009].

As with oxygen saturations, a single drop of systolic blood pressure to less than 90 mmHg doubles the patient's risk of death [Moppett, 2007]. Make sure you keep your clinician informed if you notice the blood pressure close to this value.

4.7 Spinal injuries

Spinal injuries, or more specifically spinal cord injuries (SCI), are rare, with around 1000 new cases per year [Harrison, 2007]. In adult major trauma, approximately 10% of patients will sustain a spinal fracture/dislocation, but less than 2% will sustain an SCI. The most common cause is a fall (46%), although, significantly, a third of these are falls of LESS than 2m in height. Falls are closely followed by road traffic collisions (RTC, 40%) and the other, much rarer, causes, such as sports injuries (under 3%), stabbings (1%) and shootings (0.6%). SCIs most commonly occur at the cervical level (45%), followed by thoracic (29%), lumbar (24%) and multi-level injuries (2%) [Hasler, 2011].

Risk factors for SCI include [Hasler, 2011]:

- Male sex
- Under 45 years of age
- Reduced Glasgow Coma Scale score
- Accompanying chest injury
- Dangerous mechanism (falls greater than 2 m, sports injury, RTC, shooting).

4.7.1 Recognition

The signs and symptoms also depend on the completeness of the SCI. The classic picture in complete SCI is vasodilation, flaccidity of muscles and loss of sensation below the injury, as well as loss of temperature regulation mechanisms such as vasodilation and sweating. This can lead to a poikilothermic state, where the body adopts the temperature of the surrounding environment (whether hot or cold). Depending on how high the SCI injury is the blood pressure can dramatically fall, for example to 80 mmHg systolic in high cervical injuries, but there is no compensatory tachycardia, since the sympathetic signals are blocked. In fact, parasympathetic division dominance leads to bradycardia, further reducing cardiac output. In an incomplete SCI,

there is a mixed picture of paralysis and paraesthesia, but not profound hypotension or bradycardia, making the absence of these signs unreliable in excluding SCI in unconscious patients [Harrison, 2007].

4.7.2 Pathophysiology

Key to the maintenance of homeostasis within the autonomic nervous system (ANS) are the cerebral cortex and hypothalamus, which provide appropriate excitatory and inhibitory inputs to various areas in the medulla, which plays a crucial role in cardiovascular control. This relies on feedback from afferent sensory impulses from central and peripheral baroreceptors. Thus, it is not difficult to see that SCI, depending on the level and completeness of the injury and cord interruption, can dramatically affect the body's ability to keep control of the ANS [Krassioukov, 2012].

Despite the common use of words like 'transection', 'cutting' and 'severing' of the spinal cord after a traumatic injury, in reality a spinal cord lesion (abnormality or damage) is primarily caused by ischaemic necrosis. Traumatic injury mechanisms include displacement of one or more vertebral bodies, causing compression and/or stretching of the cord, which may result in no visible injury, but leads to oedema and vascular disruption. However, not all SCI is due to trauma. Other causes include spinal tumours, transverse myelitis, vascular thrombosis or haemorrhage, and infection and abscesses caused by tuberculosis or meningitis [Gupta, 2009].

It's very cosy within the vertebral canal and an oedematous spinal cord is soon compressed. This disrupts blood and oxygen flow, resulting in ischaemic tissue and, ultimately, necrosis. The rapid cessation of signal transmission that this process causes leads to a range of signs and symptoms, which are termed 'spinal shock' [Harrison, 2007].

Nerves originating from T1 to T5 are responsible for most heart and vascular control, and injuries below this level typically do not have such a dramatic effect on the ANS. However, an injury at T6 or above can lead to interruption of sympathetic division control from the brain. Parasympathetic innervation of the heart arises from the brain and so is typically unaffected, making the parasympathetic division dominant.

4.7.3 Management

All patients who are suspected of having a spinal injury should be immobilised as soon as possible. Remember that the whole spine must be immobilised. The techniques and equipment involved in order to perform this safely are described in the SKELETAL IMMOBILISATION lesson below [AACE, 2013].

Remember that spinal immobilisation is not a risk-free procedure. Potential complications of spinal immobilisation include [AACE, 2013]:

- Airway problems (including increased risk of aspiration)
- Increased intracranial pressure
- Restricted respiration
- Dysphagia
- Skin ulceration/pressure sores
- Pain.

Patients with isolated penetrating trauma to the head or limbs do not require immobilisation, but if, in torso or neck trauma, it is possible that the projectile could have passed near or through the spinal cord and there are signs of spinal cord injury, then immobilisation is appropriate.

In blunt trauma, there are guidelines that allow clinicians to discontinue immobilisation, so you may on occasion be asked to stop immobilising a patient once a thorough assessment has been completed [AACE, 2013].

4.8 Thoracic injuries

Thoracic trauma accounts for 25–50% of all trauma and is a contributing factor to around half the deaths through injury. Major causes are road traffic collisions, industrial accidents and domestic and sporting injuries [Greaves, 2008]. The most common problem associated with severe thoracic injury is hypoxia [AACE, 2013]. This can occur due to respiratory and/or cardiovascular causes, which are summarised in Table 4.1 [Greaves, 2008].

4.8.1 Pneumothorax

The lungs are surrounded by a pleural membrane. The outer layer (parietal pleura) lines the chest wall, and the inner layer (visceral pleura) covers the lungs. Between them is the pleural space, which is lubricated to ensure that the surfaces glide smoothly over one another as well as creating a surface tension that results in the surfaces 'sticking together'.

Pneumothorax, or air in the pleural space, is generally classified as being spontaneous, if there is no obvious causal factor, or traumatic, if there is an external cause [Noppen, 2010]. In the event that air within the alveoli can escape into the pleural space, or there is an external breach of the thoracic cavity allowing atmospheric air to enter the pleural space, the normal physiology of ventilation is disrupted and the lung collapses [Ryland, 2014].

Traumatic pneumothoraces are caused by penetrating trauma, such as stab and gunshot wounds or impalements; blunt trauma that leads to rib fractures and increased intrathoracic pressure; and bronchial rupture and barotrauma, where changes in pressure of the air delivered to the lungs leads to expansion. This phenomenon has been reported in air crew and SCUBA divers [Sharma, 2008].

Open pneumothorax

In an open pneumothorax, air enters the pleural space thanks to a communication between atmospheric air and the pleural space, for example as a result of penetrating trauma. As the chest expands during inspiration, air enters the pleural space. If the wound is large enough, there may be free movement of air into and out of the affected lung during respiration. If the wound is similar in size to the glottic opening to the lower airway, then atmospheric air preferentially enters via the wound, leading to ineffective ventilation of the alveoli. The sound heard as air moves into and out of the wound has led to these types of injury being referred to as 'sucking chest wounds' [NAEMT, 2014; Greaves, 2008].

Table 4.1: Causes of hypoxia from thoracic injury

Respiratory	Cardiovascular
Tension pneumothorax	Tension pneumothorax
Open pneumothorax	Large haemorrhage
Massive haemothorax	Pericardial tamponade
Ventilatory failure (e.g. flail chest)	Rupture of major blood vessels
Pulmonary contusion	Myocardial contusion

Tension pneumothorax

Tension pneumothorax is an uncommon, but life-threatening, condition which can prove rapidly fatal to patients, particularly those who are being ventilated with positive-pressure. It most often occurs in [MacDuff, 2010]:

- Ventilated patients in intensive care
- Trauma
- Cardiac arrest
- Acute exacerbations of asthma and COPD
- Blocked or clamped chest drains
- Non-invasive ventilation.

As with other types of pneumothorax, air enters the pleural space on inspiration, but cannot escape during expiration due to the presence of a one-way valve formed by a pleural defect. This leads to increasing intra-pleural pressure on the affected side of the chest, worsening the lung collapse and causing diaphragmatic depression. In severe cases, and dependent on mediastinal distensibility, this can compress the contralateral lung.

It's worth noting that tension pneumothoraces typically develop far more slowly in spontaneously breathing awake patients, compared to ventilated and sedated patients, who can experience hypotension and a rapid decline in oxygen saturations in just a few minutes, hastened by the administration of positive-pressure ventilation [Leigh-Smith, 2005; MacDuff, 2010].

Assessment

Arguably, the most important type of pneumothorax to recognise is one under tension. However, the clinical course of a tension pneumothorax is not the same for all patients, with the progression of clinical deterioration for an awake, spontaneously breathing patient likely to be considerably longer than for those who are being ventilated with positive-pressure ventilation [Leigh-Smith, 2005].

Signs and symptoms of a tension pneumothorax in awake patients include:

- Pleuritic chest pain (sharp pain, worse on breathing in and out)
- Air hunger
- Respiratory distress
- Tachypnoea (rapid breathing rate)
- Tachycardia (rapid heart rate)

- Falling oxygen saturations (SpO_2)
- Agitation
- On the same side as the injury:
 - Hyper-expansion
 - Hypo-mobility
 - Decreased breath sounds
- Pre-terminal (near death):
 - Decreasing respiratory rate
 - Hypotension
 - Decreasing level of consciousness.

Do not rely on tracheal deviation or distended neck veins as these can be difficult to determine [Spiteri, 1988].

In ventilated patients, the clinical deterioration is likely to be far more alarming. In addition, ventilated patients are more likely to suffer a cardiac arrest, whereas awake patients tend to suffer from respiratory arrest initially [Leigh-Smith, 2005].

Management

Patients with a simple pneumothorax with no signs of cardiovascular compromise, suggesting tension, can be managed conservatively out-of-hospital, but should be closely monitored en route to hospital [Lee, 2007a]. All patients with a pneumothorax should receive oxygen at the appropriate target range (usually 94–98%, except for patients at risk of carbon dioxide retention, who should be managed at either 88–92% or their usual range [AACE, 2013]). If there is an open pneumothorax, then the wound should be covered with a commercial chest seal or an occlusive dressing, taped on three sides to act as a one-way valve [Lee, 2007a]. However, these can block, so closely monitor the patient and remove the dressing if the patient shows signs of tension pneumothorax. Patients with signs of a tension pneumothorax require prompt decompression by needle thoracentesis, which involves inserting a large-bore cannula (typically a 14 gauge needle) into the patient's chest, which should be performed by clinicians only.

4.3.2 Haemothorax

Haemothorax, or blood in the thoracic cavity, usually occurs due to penetrating trauma. Life-threatening haemorrhage can occur in cases of severe lacerations of the lung, large vessels in the mediastinum and the heart. Each hemithorax

(literally, half of the chest) can easily accommodate half of the patient's circulating blood volume before the physical signs are obvious [Greaves, 2008].

However, this amount of bleeding will lead to the signs and symptoms of shock, and since blood occupies space usually reserved for the lung, lung collapse occurs, leading to absent or decreased lung sounds and reduced chest wall expansion on the injured side [Greaves, 2008]. There are few treatment options available outside of hospital; usually, expedient transport to the nearest major trauma centre is indicated.

4.8.3 Flail chest

Blunt chest trauma can lead to multiple rib and sternal fractures. In the event that two or more ribs are broken in two or more places, the chest wall will lose the rigid structure that usually supports the chest. A flail segment will start to move paradoxically, that is, it will move inwards during inspiration and outwards on expiration. If this area is large enough, it results in compromised ventilation. However, it is usually bruising of the underlying lung that leads to hypoxia and there can also be significant blood loss, with each rib fracture causing around 100 ml of blood loss [Greaves, 2008].

The flail segment is not always obvious as muscular spasm can support the segment until the muscles are exhausted. However, these injuries are painful and your clinician is likely to want to provide intravenous analgesia [AACE, 2013]. Do not attempt to splint the flail segment as this is likely to further impair ventilation [NAEMT, 2014].

4.9 Abdominal injuries

The abdominal cavity extends from the diaphragm to the pelvic bones and from the vertebral column to the muscles of the abdomen and flanks (Figure 4.1). Organs are classed as peritoneal if they are covered by a lining called the peritoneum. These include the spleen, liver, stomach, gallbladder, parts of the large intestine and most of the small intestine, and the female reproductive organs [NAEMT, 2014]. The retroperitoneal space is the area behind the peritoneum. This area contains the kidneys, ureters, pancreas, parts of the small and large

intestine and the aorta and vena cava [AACE, 2013].

In blunt trauma, the spleen, liver and structures that are firmly fixed, such as the retroperitoneal organs, are most commonly injured due to shearing forces associated with rapid deceleration. Penetrating trauma can also cause serious damage and severe bleeding. Depending on the angle at which the penetrating object enters, thoracic injury is also possible, particularly in upper abdominal stab injuries [NAEMT, 2014]. Patients suffering from abdominal trauma may not exhibit many symptoms initially, although you should suspect internal injury in any shocked patient with a suggestive mechanism of injury. Look at the abdomen for signs of injury, such as bruising, abrasions and seat-belt marks. Gently feel the abdomen for signs of tenderness, but don't be reassured by a normal examination [AACE, 2013].

There is no specific management of blunt abdominal trauma, but in penetrating trauma, if

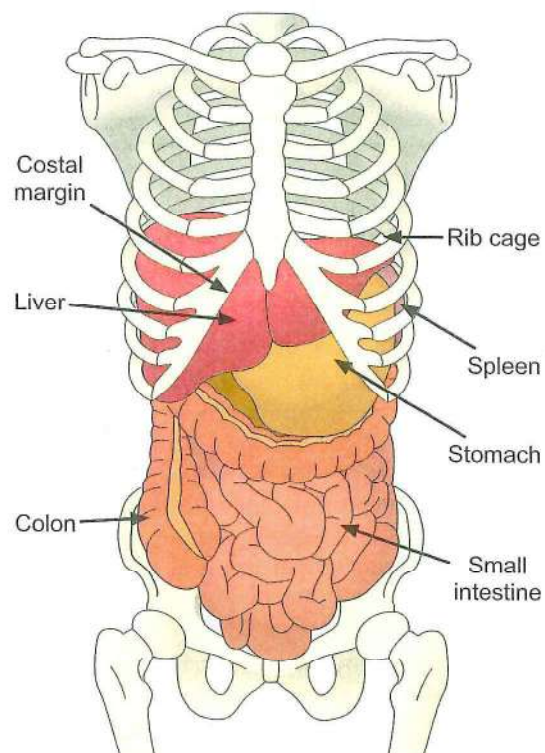


Figure 4.1 The abdominal cavity

the injury has caused the bowel to protrude out of the abdomen, you should not push it back in. Instead, cover it with a dressing soaked in warm saline [NAEMT, 2014].

If the penetrating object is still in place in the patient's abdomen, do not attempt to remove it. Instead, secure it appropriately, although if it is pulsating, allow some movement of the object, but not its removal [AACE, 2013].

4.10 Pelvic injuries

All pelvic fractures cause some bleeding, although the source can vary. Bleeding from cancellous bone that has been fractured is common, but bleeding can also occur from lacerations to retroperitoneal veins and the internal iliac arteries. Arterial bleeding accounts for up to 25% of haemodynamically unstable pelvic ring fractures [McCormack, 2010], but most bleeding is actually low-pressure bleeding (i.e. not arterial) and usually responds well to appropriate stabilisation (such as with a pelvic binder or external fixator) and tamponade [Abrassart, 2013]. Reducing the pelvic volume is an important step in controlling bleeding, as just a 3 cm gap at the symphysis pubis can lead to an increase in pelvic volume of 1.5 litres [Mears, 1986].

Associated abdominal injuries

As well as the potential vascular damage that pelvic ring fractures can cause, the soft tissues are also vulnerable, and injuries to the anorectum, vagina, urethra and nerves can occur. The most common is bladder injury, typically caused by compression or tearing of the bladder wall. Urethral and anorectal injuries are more common with straddle injuries, for example when a motorcyclist straddles the fuel tank during an RTC, resulting in the separation of the two pelvic bones and severe tearing of the pelvic floor [Luke, 2010].

Pelvic binders

If your clinician elects to apply a pelvic binder, make sure it is positioned correctly. Generally, the binder should be placed over the greater trochanters, but it is commonly placed too high [Bonner, 2011], such as over the iliac crests, which can actually compound pelvic fractures. Where possible, pelvic binders should be placed directly against the patient's skin. The correct

application of pelvic binders is reviewed in more detail in the SKELETAL IMMOBILISATION lesson.

5 Skeletal immobilisation

5.1 Learning objectives

By the end of this lesson you will be able to:

- Describe how to perform a range of skeletal immobilisation techniques.

5.2 Introduction

Skeletal immobilisation is an important skill to learn and has the following benefits when performed correctly [NAEMT, 2014; Greaves, 2008]:

- Reduces pain
- Reduces risk of further damage to soft tissues, nerves and blood vessels
- Helps to control bleeding
- Reduces risk of fat embolism.

In this lesson you will learn how to perform the following techniques and/or use the equipment listed:

- First-aid techniques
 - Triangular bandages
- Spinal immobilisation
 - Manual methods
 - Cervical collar application
 - Crash helmet removal
 - Spinal board
 - Orthopaedic (scoop) stretcher
 - Vest-type extrication devices
- Using splints:
 - Box splint
 - Pelvic splint
 - Traction splint.

5.3 First-aid techniques

Effective splinting does not have to require expensive equipment, which may or may not be available. Sometimes, it is preferable to use basic first-aid methods, such as triangular bandaging for the management of upper limb injuries.

5.3.1 Triangular bandages

Triangular bandages have three main uses:

- Folded as a broad- or narrow-fold bandage to immobilise and support a limb or to secure a splint or bulky dressing
- Opened to form a sling
- Folded into a pad and used as a dressing.

In the ambulance service, it is probably most commonly used to make a sling to hold an injured limb close to the body and take some of the weight of that limb to prevent pain. Usually, the arm sling is used for injuries at the elbow or below and the elevated sling for injuries above the elbow. However, there is little evidence to support the benefit of either technique over the other and it is acceptable to adopt the technique that is most comfortable for the patient [Gregory, 2010b].

Procedure – Arm sling

Take the following steps to apply an arm sling [SJA, SAA, BRC, 2014; Gregory, 2010b]:



1. Explain the procedure to the patient and obtain informed consent. Provide analgesia as required to enable the sling to be applied. Prepare the triangular bandage



2. With the patient supporting their injured arm with the uninjured arm, ask them to flex the elbow to 90° if possible



3. Slide the triangular bandage under the patient's arms so that the point is under the injured arm and the base (the long edge) is on the side of the uninjured arm



4. Slide the upper end of the triangular bandage around the neck towards the injured shoulder

Procedure continued →



5. Fold the lower end of the bandage up over the forearm and bring it to meet the other end of the bandage at the shoulder



6. Tie the ends together using a reef knot. Consider applying a pad under the knot, if required



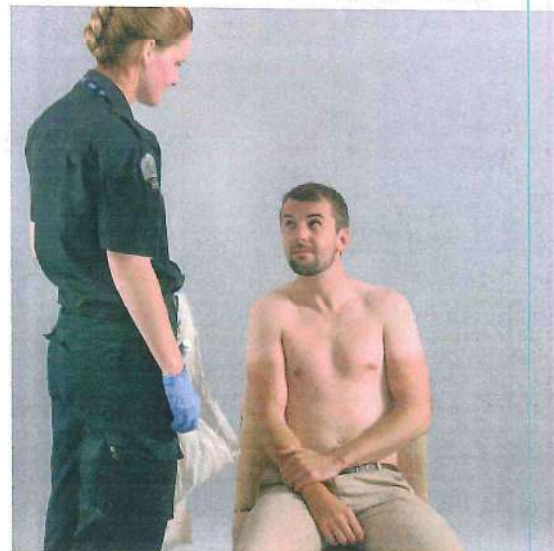
7. Holding the point of the bandage beyond the elbow, twist the point of the bandage until it fits the elbow snugly, then tuck it into the bandage. An alternative is to use tape or a safety pin



8. Re-check and record motor/sensory/circulation (MSC) function

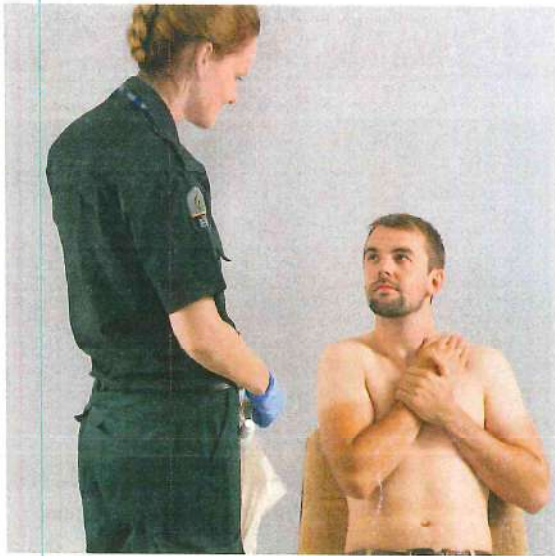
Procedure – Elevated sling

Take the following steps to apply an elevated arm sling [SJA, SAA, BRC, 2014; Gregory, 2010b]:



1. Explain the procedure to the patient and obtain informed consent. Provide analgesia as required to enable the sling to be applied. Prepare the triangular bandage

Procedure continued →



2. Ask the patient to support their injured arm across their chest, with the fingers of the injured arm resting on the opposite shoulder



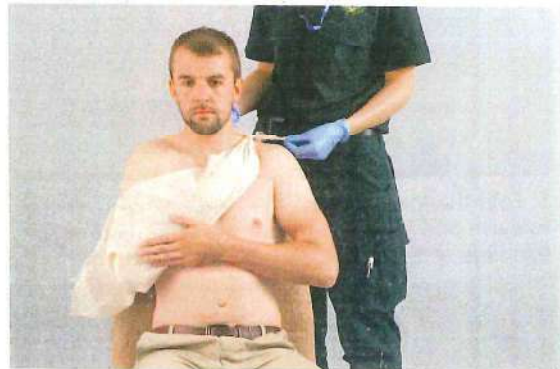
3. Place the sling over the injured arm so that the point of the bandage lies just beyond the elbow



4. Ask the patient to let go of their injured arm. Tuck the base of the bandage under their lower arm



5. Bring the lower end of the bandage up diagonally across the patient's back to meet the other end at the shoulder



6. Tie the ends together using a reef knot. Consider applying a pad under the knot, if required



7. Holding the point of the bandage beyond the elbow, twist the bandage until it fits the elbow snugly, then tuck it into the bandage. An alternative is to use tape or a safety pin

Procedure continued →



8. Re-check and record motor/sensory/circulation (MSC) function

5.4 Spinal immobilisation

Spinal immobilisation should be considered for any trauma patient with [EEAST, 2014]:

- A mechanism of injury consistent with spinal injury (mechanism may be minimal in the elderly or those with fragility conditions e.g. osteoporosis)
- Glasgow Coma Scale score of less than 15
- Complaints of neck or back pain
- Signs or symptoms of spinal cord injury
- Drug/alcohol intoxication.

5.4.1 Manual in-line stabilisation

Manual in-line stabilisation (MILS) with adequate back support is one of two acceptable methods of immobilisation. The other requires the use of several items of equipment [AACE, 2013]. Therefore, MILS will almost always be the first form of spinal immobilisation to be applied to a patient with a suspected spinal injury.

Procedure

Take the following steps to apply manual in-line stabilisation [NAEMT, 2014; Pilbery, 2013]:

1. Use appropriate PPE as required. Advise the patient not to move their head, explain that you are about to hold their head, and gain their consent if possible.
2. If the patient is supine (lying on their back) either kneel or lie on the ground behind the patient's head. If seated, move behind the patient. Hold the head firmly with both hands. Support the lower jaw with your fingers and support the head with your palms. Try to rest your lower arms on a surface (such as the ground or the back of a seat) as maintaining MILS can be tiring.

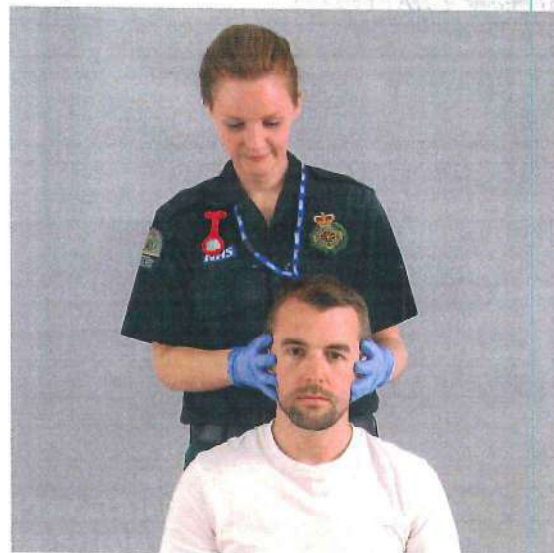
3. If the patient's head is not facing forwards and the patient is conscious, ask them to slowly move their head into a neutral, in-line position (eyes looking straight ahead and nose in line with umbilicus). If the patient is unconscious, gently move the head into a neutral position. If there is any pain or resistance to this manoeuvre, stop immediately.
4. Do not let go until instructed to do so by a clinician.

5.4.2 Cervical collars

The most important thing to know about cervical (semi-rigid) collars is that they do not fully immobilise the cervical spine [NAEMT, 2014; James, 2004]. Until head blocks and a back support are in place, manual in-line stabilisation must be used.

Procedure in the SITTING position – Ambu Perfit adjustable collar for extrication (ACE)

Take the following steps to apply a cervical collar when the patient is in a sitting position [Ambu, 2011]:



1. Use appropriate PPE as required. Inform the patient and obtain consent, if possible. One crew member should maintain manual in-line stabilisation while the other prepares the collar

Procedure continued →



2. Ensuring the head is in a neutral position, size the collar by measuring the distance with your fingers between an imaginary line drawn horizontally and immediately below the patient's chin, and another immediately on top of the patient's shoulder



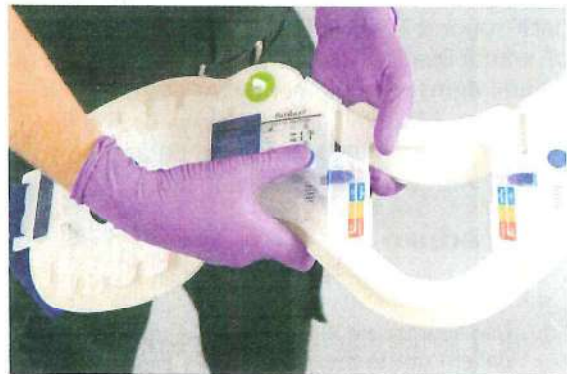
3. Compare this distance with the distance from the collar sizing line to the lower aspect of the plastic collar (NOT the foam)



4. The Perfit ACE collar is preset to neckless size 3. If a larger size collar is needed, disengage the safety locks by pulling UP on the buttons



5. Adjust the collar to the correct size. There are 16 ratchet settings; simply pull the collar apart until the distance between the sizing line and the plastic collar body is the same as your finger measurement in step 2



6. Engage the safety locks by pushing DOWN on the safety buttons

Procedure continued →



7. If the collar requires resizing, disengage the safety locks and pull OUT on the ratchet latches. Once resized, push the arrows IN and the safety locks DOWN



8. Assemble the collar by holding it near the tracheal opening and flip over the chin piece from the back of the collar to the front



9. Preform the collar



10. Slide the front of the collar along the patient's chest and position the chin piece so that the chin is supported. The collar body should rest on top of the patient's shoulder and against the sternum without gaps. The patient should remain in neutral alignment



11. While holding the front of the collar in place, wrap the back of the collar around the back of the patient's head and neck and secure to the front of the collar with the Velcro tab. Maintain MILS