Chapter 14: Transportation medicine.

Goals:

Introduction
Transportation law
Transportation ‘under the influence’
Personal transport and road traffic injuries
Railway injuries
Aircraft fatalities
Marine fatalities

Notes:

Important ones are in red.
** Focus on the type of injury.*

- Simpson's Forensic Medicine 13th ed. - J. Payne-James, et. al., (Hodder-Arnold, 2011) BBS

Summary ☺.

Most important slide.💙

* Pedestrians struck by motor vehicles suffer injuries from direct contact with the vehicle **(primary injuries)** or from contact with other objects, or the ground, after the primary contact with the vehicle **(secondary injuries).**

*** The primary injuries** can often come form recognizable patterns, although a variety of factors may alter the eventual constellation of injury. When an adult is hit by the front of a car, **for example,** the front bumper (fender) usually strikes the victim at about **knee level.** The exact point of contact, however, whether on the front, side or back of the leg(s), will depend on the orientation of the victim, the nature of the front of the car, and whether or not it is actively braking at the time of impact. Comparison of measurements of lower limb injuries (from the heel), with measurements of relevant parts of the car (from the ground) may assist in the reconstruction of pedestrian versus car collisions.

*** Secondary injuries** are often more serious, and potentially lethal, than the primary injuries. Such secondary injuries vary from simple **'brush abrasions',** caused by 'skidding' across the surface of the road, to fractures of the skull or axial skeleton, caused by direct contact with a hard surface, to hyperextension or hyperflexion fractures of the spine.

- It is important to remember that the external injuries are seldom lethal *per se*y, it is their association with internal injuries that is important.
- Even in the absence of skull fracture, traumatic brain damage, including traumatic axonal injury, is frequently observed in fatally injured pedestrians. This occurs as a consequence of the rotational, deceleration forces produced when the rapidly moving head is suddenly stopped at impact, leading to 'shearing' injuries to the brain and its coverings. **Fractures of the spine,** especially in the cervical and thoracic segments, may lead to cord damage.

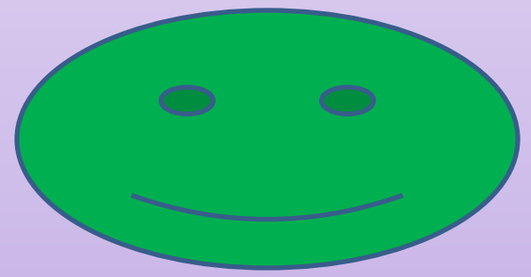
*** The unrestrained rear-seat passenger is also liable to injury through either deceleration or acceleration.**

* Abrasions caused by contact with the road surface are almost universal following an accident at speed, and injuries to the limbs and to the chest and spine occur very commonly because of contact with other objects or vehicles, entanglement with the motor bike or direct contact with the road

* Large aircraft are pressurized and, if the integrity of the cabin is breached, there can be rapid decompression and the passengers may suffer barotrauma.

Introduction

All forms of transport (air, water or land) are associated with a risk of harm or injury. Particular environments render individuals at risk of specific types of injury. The incidence of those risks may be well established but can be increased when other factors are taken into account, including lack of experience, fatigue and the effects of drugs and alcohol.



Transportation law

- every jurisdiction has laws that control the speed at which vehicles can move and the amount of alcohol and/or drugs under which an individual is lawfully deemed to be capable of controlling, or being in charge of, a means of transportation.
- The basis of such laws is quite simple: the faster you are travelling, the greater the risk of loss of control and collision, and the greater the level of injury, the more intoxicated you are, the greater the chance of collision.
- Legal limits are established for acceptable levels of alcohol in blood, breath or urine.
- in the UK, the maximum legal blood alcohol concentration is 80 mg alcohol/100mL of blood, although this is hopefully going to be reduced in the future to 50 mg alcohol/100mL of blood.
- The assessment of the effects of drugs and alcohol on ability to drive is very important because of the variable individual response to the effects of alcohol and other substances.
- In many cases, 'driving under the influence' may be confirmed by the ability, or failure, to pass standardized tests of sobriety, or by medical examination to determine whether the ability to drive may be impaired, following preliminary impairment tests undertaken by police personnel.
- In all cases it is perceived that such individuals, or bodies, may have a duty of care to those around them, whether as private individuals (e.g. friends being given a ride to a party) or as paying clients (e.g. customers paying for transport across the sea).
- In England and Wales, The Transport and Works Act 1992 defines specific offences related to the use of alcohol and drugs in transport systems, and defines the powers that police have to investigate such matters, including the power to take evidential breath, blood and urine tests.
- This area of law is vast, and varies from jurisdiction to jurisdiction, but increasingly legal action is being taken at a higher corporate level such that accountability is required throughout all levels of an organization.
- **The Corporate Manslaughter and Corporate Homicide Act 2007 came into force in 2008 and introduced a new offence, across the UK: corporate entities (companies and organizations) may now be prosecuted when there has been a gross failing, throughout the organization, in the management of health and safety where such a failure has fatal consequences.**

Transportation ‘under the influence’

- In general, two types of offence are committed when ‘under the influence’ of alcohol or drugs. Relevant maximum permissible alcohol concentrations can be prescribed and quantified in an individual, but in many jurisdictions the effect that alcohol (or drugs) has on the ability to drive properly must also be assessed. Initial screening may be done by officers at the scene of an alleged offence or accident, using **‘field impairment tests’.**

- Evidential **‘breath alcohol machines’** are used to take breath samples, and if for some reason (e.g. asthma, oral trauma) it is not possible for an individual to provide a sample, then blood or urine samples must be sought.
- The experience in all jurisdictions is that individuals (who might suspect they exceed the relevant legal limit) may provide a variety of reasons for not providing relevant samples (e.g. previously **undiagnosed asthma, needle phobia**) and, although some of those reasons may be valid, many have been tested in court and found wanting.
- The medical assessment of an individual’s ability to drive a motor vehicle is established by **(1) undertaking a full history and examination and (2) undertaking a number of tests of coordination and reactions**.
- **The aim of the examination is to determine**
- **(1)** whether the individual’s ability to drive is impaired
- **(2)** which drug/substance is causing this impairment
- **(3)** whether there is a medical reason for the individual’s apparently impaired status (e.g. neurological disorder, psychiatric disorder).
- Increasingly, certain procedures that measure psychomotor function and ‘divided attention tests’ are used.
- **Divided attention tests**, which assess an individual’s balance and coordination, as well as the ability to follow simple instructions, include the ‘walk and turn test’, ‘one-leg stand test’, ‘horizontal gaze nystagmus test’ and Romberg test.

- If such tests are used, it is important they are reproduced and scored in identical ways.
- It is also important to understand that initial studies, which suggested high sensitivities and specificities in results for Drug Recognition Programs within the USA, have not been confirmed in controlled laboratory studies.
- The results of the few studies that have been performed suggest that the accuracy of such assessment, in general, may not be sufficiently robust for evidential purposes (in terms of determining the culpable drug/substance), but they can help corroborate other witness and toxicological evidence.
- Many individuals will have used a mixture of drugs and alcohol, which often renders tests for specific drugs groups inappropriate or wrong.
- It is important to recognize that the results of 'field impairment tests' ('preliminary impairment tests' in the UK) do not necessarily establish impairment of driving through drugs other than alcohol, although they may be useful in screening individuals suspected of being impaired as a consequence of drug use, and provide supportive evidence of impairment., **They cannot be used with certainty to confirm that drugs have been used, or the particular drug or drugs that may have consumed.**
- Anyone using these tests, in association with a medical examination, must be able to interpret them in the context of that medical examination, the circumstances in which field tests were undertaken, and the limitations of the evidence base on which such screening tests are established.

Personal transport and road traffic injuries

- Those injured by collisions on the road, or off- road using personal transport can be divided into **three** broad groups: pedestrians, cyclists (pedal or motor) and the drivers or passengers of vehicles.
- Of these three broad groups, it is **pedestrians** **who are most often injured**, although the proportion of pedestrian victims in the overall road traffic- injured population varies greatly between countries depending on patterns of transport use, It is perhaps self-evident that where there is greater mingling of motor transport and pedestrians there is also a greater risk of injury to the pedestrian. Most road deaths in the world occur in developing countries.

Pedestrians:

- Pedestrians struck by motor vehicles suffer injuries from **direct contact with the vehicle** **(primary injuries)** or from contact with other objects, or the ground, after the primary contact with the vehicle **(secondary injuries)**
- Advances in safer vehicle design and legislation have attempted to reduce the effects of such contact but cannot eradicate them completely.
- **The primary injuries** can often form recognizable patterns, although a variety of factors may alter the eventual constellation of injury.
- When an adult is hit by the front of a car, **for example,** the front bumper (fender) usually strikes the victim at about **knee level.** The exact point of contact, however, whether on the front, side or back of the leg(s), will depend on the **orientation of the victim, the nature of the front of the car, and whether or not it is actively braking at the time of impact**.
- Comparison of measurements of lower limb injuries (from the heel), with measurements of relevant parts of the car (from the ground) may assist in the reconstruction of pedestrian versus car collisions (Figure 14.1).

Figure 14.1 **(a)** A pedestrian struck by the front of a car may be projected forwards or lifted onto the vehicle; **(b)** 'bumper injuries' including a compound fracture of the right leg, and laceration of the left knee, probably following primary impact to this pedestrian's right leg.

- There are often additional primary injury sites on the thigh, hip or pelvis caused by contact with other parts of the car, such as the **bonnet (the hood).** At relatively low speeds (e.g. 20 kph/12 mph), the victim may be thrown off the bonnet either forwards or to one side.
- Between **20 and 60 kph** (12–36 mph), the pedestrian may strike the bonnet (hood) and the head may strike the windscreen or the surrounding metal body work.
- At higher speeds (60–100 kph/36–60 mph), pedestrians may be **projected up into the air; sometimes they will pass completely over the vehicle and will avoid hitting the windscreen and other points on the vehicle** (Figure 14.2).
- Such impacts, however, will generally cause **major** injury, including **complex fractures or traumatic amputations.**
- **Secondary injuries** are often more serious, and potentially lethal, than the primary injuries. Such secondary injuries vary from simple **'brush abrasions',** caused by 'skidding' across the surface of the road, to fractures of the skull or axial skeleton, caused by direct contact with a hard surface, to hyperextension or hyperflexion fractures of the spine.

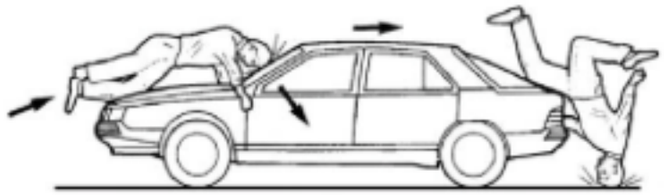


Figure 14.2 At speeds of over 23 kph (15 mph) a pedestrian can be 'scooped up' onto a car, suffering head injuries on impacting the windscreen. They may then fall off sideways or, at higher speeds, be thrown over the roof.

Cont'd

- It is important to remember that the external injuries are seldom lethal *per say,* it is their association with internal injuries that is important.
- Even in the absence of skull fracture, traumatic brain damage, including traumatic axonal injury, is frequently observed in fatally injured pedestrians.
- This occurs as a consequence of the rotational, deceleration forces produced when the rapidly moving head is suddenly stopped at impact, leading to '**shearing**' injuries to the brain and its coverings.
- **Fractures of the spine,** especially in the cervical and thoracic segments, may lead to cord damage.
- Fractures of the limbs are common but, apart from those of the legs that are associated with the primary impact sites, they are somewhat unpredictable because of random 'flailing' of the limbs following primary impact.
- When an adult is struck by a larger vehicle, for example a van, a 4 × 4, a sport utility vehicle (SUV), truck or lorry, or when a small child is struck by any vehicle, the typical lower limb primary contact injury site described above tends to be 'higher up' (pelvis, abdomen, chest or head).
- It is likely that the victim will make contact with more of the front of the vehicle or be projected along the line of travel of the vehicle and 'run-over'.
- **'Run-over' injuries are relatively unusual and the effects are variable, depending on the area of the body involved, the weight of the vehicle and the surface area of the contact.**
- The skull may be disrupted and the brain externalized, internal organs may be ruptured and there may be fractures of the spine.
- Compression of the chest may result in multiple rib fractures, causing a 'flail chest'.
- **The rotation of the wheel may strip off large areas of skin and subcutaneous tissue; this is called a 'flaying injury'** (Figure 14.3).
- On occasion, patterned injuries are recognized on the skin surface bearing the characteristics of tyre-treads (Figure 14.4).

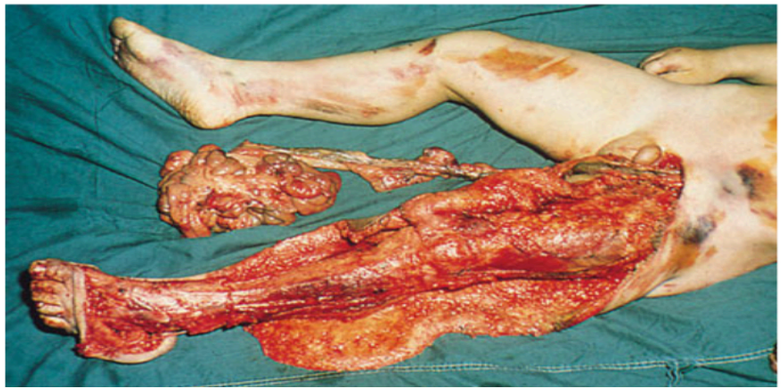


Figure 14.3 Pedestrian leg injury from a rotating wheel resulting in 'flaying' of the skin.

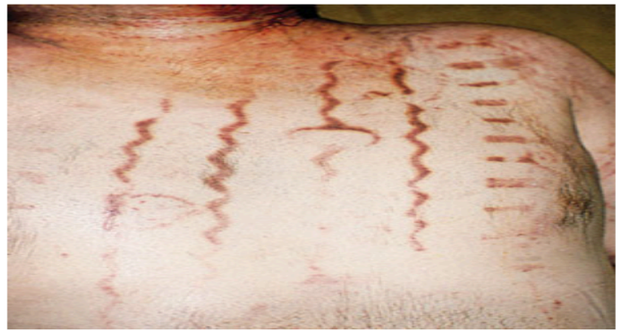


Figure 14.4 Intradermal bruising reflecting the pattern of a vehicle tyre tread. Note that the bruising is in the 'valleys' and not the 'hills' in the tread. Scaled photographic documentation of such a patterned injury will allow future comparisons to be made between it and the tread pattern of a suspect vehicle.

Car occupants:

- Most impacts involve the front, or the front corners, of the vehicle and approximately 80 per cent of impacts are against either another vehicle or a stationary object, This type of impact rapidly decelerates the vehicle.
- Less commonly, the vehicle is hit from behind, causing an **'acceleration' impact.**
- **The least common impacts are side impacts and 'roll-overs'.**
- Many countries now have legislation regarding the requirement to wear seatbelts, both in the front and back of moving vehicles. Unrestrained front-seat occupants in a vehicle subjected to rapid deceleration during a collision **will continue to move forwards as the vehicle decelerates around them, and will impact those parts of the vehicle that are in front of them**.
- The degree of injury sustained by the occupant is very much **dependent on the vehicle's speed at the moment of impact**, its deformation properties and the structure of the part (or parts) of the vehicle being impacted by the occupant (Box 14.1, Figures 14.5–14.7).
- **The unrestrained rear-seat passenger is also liable to injury through either deceleration or acceleration.**
- The injuries, in general, may not be as severe as those caused to the front-seat occupants.
- In a deceleration impact, the rear- seat passengers **will be thrown against the backs of the front seats** and may impact the front-seat occupants. They may be projected over the front seat to hit the windscreen and even be thrown out through the windscreen.

Box 14.1 Injuries that may be expected to occur in an unrestrained impact/collision

- The face and head hit the windscreen glass, frame or side-pillars, causing skull and facial fractures, injury to the brain and its coverings, and cervical spine injury.
- The chest and abdomen contact the fascia or the steering wheel, causing rib, sternal, heart and liver injuries.
- The momentum of the heart within the thorax, perhaps aided by hyperflexion, may tear the aorta at the termination of the descending part of the arch, at the point where the vessel becomes attached to the vertebral column.
- The legs of the passenger are thrown forwards and the knees may strike the parcel shelf, causing fractures.
- The legs of the driver, which are commonly braced on the brake and clutch pedals, may transmit the force of impact along the tibia and femur to the pelvis. All of these bones may be fractured or dislocated.
- On the rebound from these impacts, the heavy head may swing violently backwards and cause injury to the cervical or thoracic spine.
- The occupants of the car may be ejected out of the vehicle through the windscreen, increasing the risks of secondary injuries or being run over by another vehicle.

Figure 14.6 Facial injuries from shattered windscreen glass in an unrestrained driver. The toughened glass breaks into small fragments, which produce characteristic 'sparrow foot' marks. The forehead laceration was made by the windscreen rim.

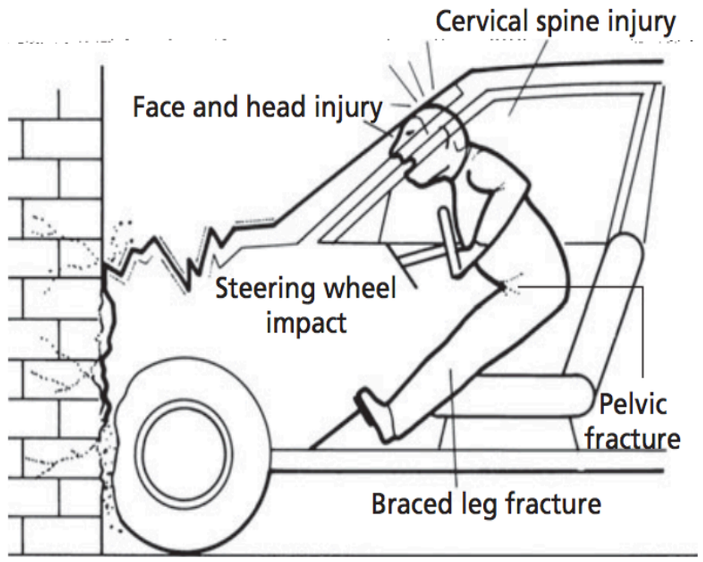


Figure 14.5 Major points of injury to an unrestrained driver of a vehicle in deceleration impact.

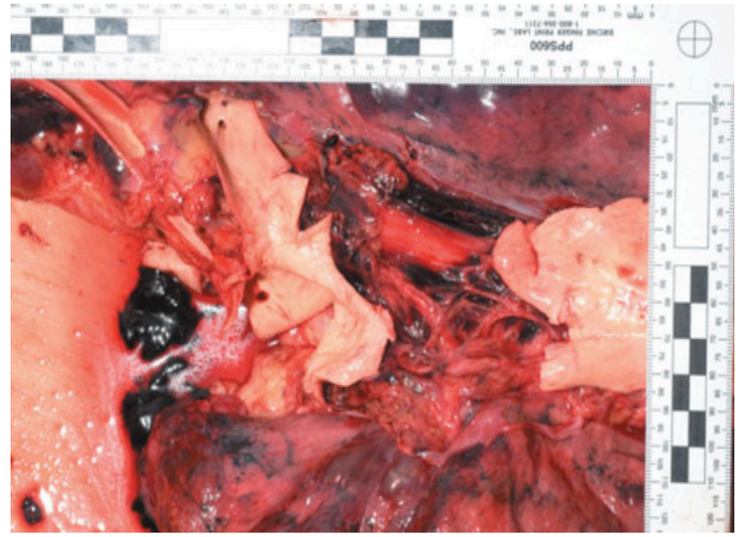


Figure 14.7 Deceleration-related thoracic aortic transection following a road traffic collision. The typical site for deceleration aortic injury is just distal to the origin of the left subclavian artery.

The function of seat belts:

- The introduction of seatbelts has dramatically reduced the number and severity of injuries to car occupants in jurisdictions where they are compulsory.
- The mandatory use of seat belts has had a profound effect on road traffic fatality rates in the UK and other countries where similar legislation has been enacted.
- The combination of a horizontal lap strap and diagonal shoulder strap was introduced as a satisfactory compromise between effectiveness and social acceptability.
- To be effective, a seatbelt must be worn correctly and any alteration in their

fixing or structure can negate their value (Box 14.2).

Box 14.2 The function of seat belts

A seat belt that is correctly installed, and worn, acts in the following ways:

- It spreads the deceleration forces at impact over the whole area of contact between the straps and the body surface so that the force delivered to the body per unit area is reduced.
- It is designed to stretch during deceleration and some belts have a specific area for this to occur. This stretching slightly extends the time of deceleration and reduces the force per unit time.
- It restrains the body during deceleration, keeping it away from the windscreen, steering wheel and other obstructions at the front of the vehicle, thus reducing injury potential.
- It prevents ejection into the road through burst doors or windows, which used to be a common cause of severe injury and death.

- The use of seatbelts can also cause injuries, the nature and severity of which is dependent on the force and nature of the impact.
- Any individual involved in a collision in which intrusion into the cabin has occurred, or where they have been trapped within the vehicle, should have a full medical assessment, as should anyone under the influence of drugs or alcohol at the time of a collision, as such may mask significant symptoms of trauma.
- Such an assessment should always include, in addition to basic physiological observations, palpation and testing of range of movement of all limbs, palpation of the clavicle, lateral and anteroposterior compression of the chest, and a full abdominal examination, in order that occult fracture or internal organ injury is not missed.

Air bags

- Air bags were developed in an attempt to aid the protection of all car occupants following a collision by rapidly deploying a 'soft method of restraint' that is only present when required.
- Most modern cars now have sophisticated air-bag systems, many pro-viding protection not only from front impacts but also from the sides or corners of the vehicle.
- The deployment of an air bag relies upon the explosive production of gas, usually from the detonation of a pellet commonly made of sodium Azide.
- For the deployment to be timed correctly, the deceleration of the vehicle following impact needs to be sensed and the detonation of the pellet completed in microseconds so that the bag is correctly inflated at the time the occupant of the car is beginning to move towards the framework of the vehicle.
- Air bags are designed to provide protection to the 'average-sized adult' in the front of the car and this protection depends upon the occupant responding to the impact in an 'average' fashion.
- Air bags can cause injuries, **most frequently abrasions or burns,** and guidelines exist as to the minimum size that a person should be when sitting in an air-bag protected seat.
- Most cars have the option of disabling air bags if those of short stature (generally children) are occupying such seats.
- **Air bags, in general, should never be used in the presence of baby seats.**
- At particular risk **are babies who are placed on the front passenger seat in a rear-facing baby seat that is held in place by the seat belt.**
- The back of the baby seat may lie within the range of the bag when it is maximally expanded, and fatalities have been recorded following relatively minor vehicle impacts when the air bag has struck the back of the baby seat.

Motorcycle and pedal cycle injuries

- Most injuries to motorcyclists are caused by falling from the machine onto the roadway.
- Many of the injuries can be reduced or prevented by the **wearing of suitable protective clothing and a crash helmet**.
- Abrasions caused by contact with the road surface are almost universal following an accident at speed, and injuries to the limbs and to the chest and spine occur very commonly because of contact with other objects or vehicles, entanglement with the motor bike or direct contact with the road (Figure 14.8).
- Despite the introduction of the mandatory wearing of crash helmets in the UK, head injuries are still a common cause of morbidity and mortality.
- In countries where there is no mandatory requirement for motorcycle helmets, the incidence is substantially increased.
- A more unique injury occurs from 'tail-gating', where the motorcyclist drives under the rear of a truck, causing severe head injuries or even decapitation.
- This injury has been reduced by the presence of bars at the sides and rear of trucks to prevent both bikes and cars passing under the vehicle.
- Injuries associated with pedal cycles are very common because of the large numbers of cycles in use.
- Most injuries associated with cycles tend to be of mild or moderate severity because of their low speeds, However, impact by vehicles can result in severe and fatal injuries.
- Secondary injuries, especially to the head and chest, are common when cyclists fall from their relatively high riding position on such an inherently unstable machine.
- Other transportation methods (e.g. the Segway Personal Transporter) may also have their own types and range of risk of injury or fatality.

Figure 14.8 Extensive 'brush' abrasion of the left flank in a motor cyclist thrown across a rough surface.

Railway injuries

- These are most common in countries with a large railway network, such as India and China, and in countries where rail crossings are unprotected or unmanned.
- Although mass disasters, such as the derailment of a train, occasionally lead to large numbers of casualties, most deaths and injuries occur as an aggregation of numerous individual incidents, most of which are accidents, such as at level crossings or as a result of children playing on the line.
- **Railway lines are a common site for suicide attempts**.
- Medically, there is nothing specific about railway injuries except the frequency of very severe mutilation.
- The body may be severed into many pieces and soiled by axle grease and dirt from the wheels and track.
- Where passengers fall from a train at speed, multiple injuries caused by repeated impacts and rolling may be seen, often with multiple abrasions from contact with the coarse gravel of the line ballast.
- Suicides on railways fall into two main groups: **those that lie on the track** (sometimes placing their neck across a rail so that they are beheaded) and **those that jump in front of a moving train from a platform, bridge or other structure near to the track**, Jumping from a moving train is much less common.
- The injuries present will depend on the exact events, but they are usually extensive and severe when there has been contact with a moving train, although they may be localized with black soiling at the crushed decapitation or amputation site if the individual has lain across the track (Figure 14.9).
- There is a risk of secondary injury if survival occurs where other factors such as electrified lines are present.
- On electrified lines, an additional cause of suicidal or accidental injury or death is present in the form of **electric shock** from either a live rail or overhead power lines.
- The voltage in these circuits is high, often in region of 600 V, Death is rapid and often associated with severe burns at the points of contact or earthling.
- A careful search for unusual injuries inconsistent with the setting, and examination for a vital response to the severe blunt force injuries, should be made, as homicides may be concealed by staging the scene, with the deceased being placed on the rail track in an attempt to conceal the true cause of death.
- Railway workers may be injured or killed by falling under, or by being struck by, moving rolling stock or by being trapped between the buffers of two trucks while uncoupling or coupling the rolling stock.
- The injuries associated with the squeezing between rolling stock are often those of a **flail chest**, with or without evidence of traumatic asphyxia.

Figure 14.9 Amputation of the right arm and bruising of the face and chest in a pedestrian struck by a passing train.

Aircraft fatalities

- Aviation incidents can be divided into two main groups: those that involve the crew and the large numbers of passengers of a modern, commercial aircraft, and those that involve the occupants of small, relatively slow, light aircraft.
- **Large aircraft are pressurized and, if the integrity of the cabin is breached, there can be rapid decompression and the passengers may suffer barotrauma.**
- If the defect in the cabin is large enough, victims may exit through the defect and fall to their death.
- When an aircraft hits the ground, the results will depend on the rapidity of transfer of the forces, and this is dependent on the speed of the aircraft and the angle of impact.
- If the forces are very severe, all passengers may be killed by deceleration injuries and by multiple trauma owing to loss of integrity of the fuselage.
- In lesser impacts, the results may be similar to those of motor vehicle crashes, although the forces are usually greater and the injuries sustained are proportionately more severe.
- The usual lap-strap seat belt offers little protection in anything but the most minor accident.
- **Fire is one of the greatest hazards in air crashes and accounts for many deaths.**
- In light aircraft crashes, the velocity, and hence the forces, may be less than in large commercial air- craft, but they are still often fatal.
- The investigation of air accidents is a task for **specialist medical personnel**, who are often available from the national air force or from a civil authority.
- **There should always be a full autopsy on the pilot or suspected pilot, with full microscopic and toxicological examination to exclude natural disease, drugs and alcohol.**

Marine fatalities

- Fatalities in the marine setting embrace a range of marine-specific and general injury types.
- The range of activities include commercial diving, recreational diving, use of powered water sport bikes, sailing, motor cruising and commercial marine transport (e.g. oil tankers, container ships, passenger vessels).
- **The likelihood of dying in a marine environment is enhanced by not wearing appropriate safety gear.**
- In the recreational setting, fatalities occur when individuals fall from vessels and drown, or succumb to hypothermia, or cannot be recovered back on board.
- Physical injuries in recreational sailing are widespread and examples include those of suffering direct trauma (e.g. head or neck following uncontrolled gybe; Figure 14.10),
- loss of digits or limbs when caught up in winches or anchor cable, limb fractures or skull fractures from direct impact from flailing blocks and burn injury from uncontrolled rope movement.
- Drowning may occur from being trapped after inversion of the vessel.
- Motor-powered vessels may cause injury from explosion or fire, or those in the water may sustain injury from rotating propellers.
- Commercial vessels may cause their own specific problems, such as asphyxiation in storage tanks or falls from heights. Most of these scenarios are of an industrial/occupational nature and may involve potential breaches of health and safety legislation. In the UK The Marine Accident Investigation Branch (MAIB) examines and investigates all types of marine accidents to, or on board, UK ships worldwide, and other ships in UK territorial waters.

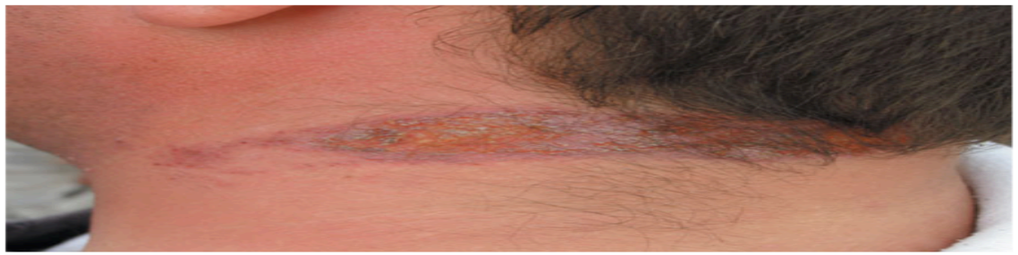
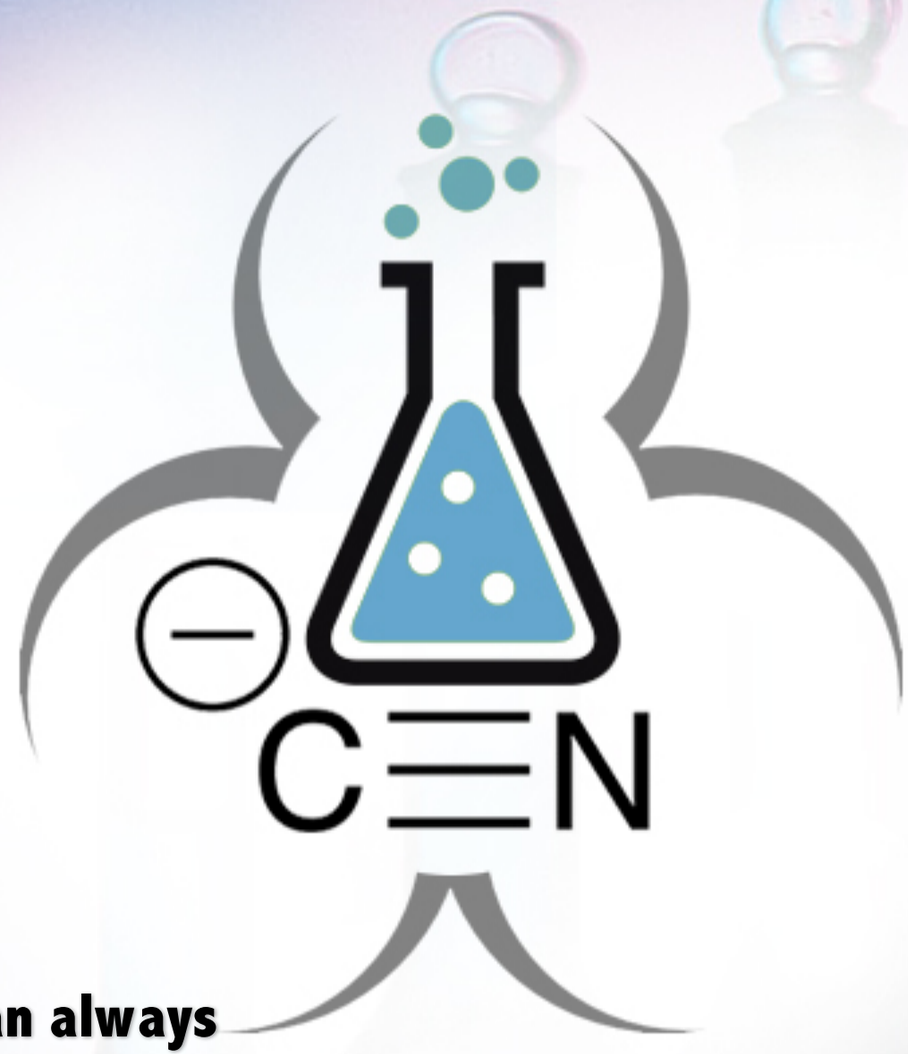


Figure 14.10 Abrasion of neck caused by mainsheet during uncontrolled gybe.



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