17 Trauma Systems and Mechanism of Injury

Competency Areas

Area 1: Professional Responsibilities

1.4.a Function within relevant legislation, policies, and procedures.

Area 4: Assessment and Diagnostics

4.2.f Obtain information regarding incident through accurate and complete scene assessment.
4.3.a Conduct primary patient assessment and interpret findings.
4.3.b Conduct secondary patient assessment and interpret findings.
4.3.n Conduct multisystem assessment and interpret findings.

Area 6: Integration

6.1.g Provide care to patient experiencing illness or injury primarily involving musculoskeletal system.
6.1.o Provide care to patient based on understanding of common physiological, anatomical, incident, and patient-specific field trauma criteria that determine appropriate decisions for triage, transport, and destination.
6.3.a Conduct ongoing assessments based on patient presentation and interpret findings.
6.3.b Re-direct priorities based on assessment findings.

Area 7: Transportation

7.4.b Recognize the stressors of flight on patient, crew, and equipment, and the implications for patient care.

Appendix 4: Pathophysiology

C. **Respiratory System**
Traumatic Injuries: Penetrating injury
E. **Gastrointestinal System**
Traumatic Injuries: Abdominal injuries—penetrating/blunt
H. **Musculoskeletal System**
Skeletal Fractures: Appendicular
Skeletal Fractures: Axial
J. **Multisystem Diseases and Injuries**
Trauma: Assault
Trauma: Blast injuries
Trauma: Falls
Trauma: Rapid deceleration injuries

Introduction

Trauma, defined as a transfer of energy applied clinically, is the leading cause of death in Canadians younger than age 45. With improvements in health care and management of chronic diseases, death rates due to conditions such as heart disease, neoplasms, cerebrovascular events, and respiratory illnesses have decreased significantly in younger age groups. Unintentional trauma, often referred to as the "silent epidemic," represents a major health concern. It has been estimated that 90% of these injuries are preventable. In Canada, trauma accounted for 7,076 deaths and almost 2 million hospital days in 2004.

Basic concepts of the mechanics and biomechanics of trauma will help you analyze and manage your patient's injuries. Analyzing a trauma scene is a vital skill because you are the eyes and ears of the emergency department physicians at the scene of the trauma. Your paramedic-written patient history and verbal reports are the *only* source for physicians and surgeons to understand the events and mechanisms that led to your trauma patient's injuries. Your information is critical as a foundation to visualize and search for injuries that may not be apparent on physical examination.

Trauma, Energy, Biomechanics, and Kinematics

Trauma is the acute physiologic and structural change (injury) that occurs in a patient's body when an external source of energy dissipates faster than the body's ability to sustain and dissipate it Figure 17-1.

If your patient's body is in a vehicle that smashes into a wall, the energy delivered by the moving vehicle is released when the car is stopped by the wall. Your patient's body is moving at the same speed as the vehicle, and his or her body does not have bumpers to absorb the energy from stopping. If the energy is not absorbed in other ways, the patient's body absorbs it, often causing bones to break and internal organs to rupture—what you see as traumatic injuries.

Different forms of energy produce different kinds of trauma. These external energy sources can be mechanical, chemical, thermal, electrical, and barometric.

Mechanical energy is energy from motion (kinetic energy ie, a moving vehicle) or energy stored in an object

At the Scene

The top five causes of trauma death are motor vehicle collisions, falls, poisonings, burns, and drownings.

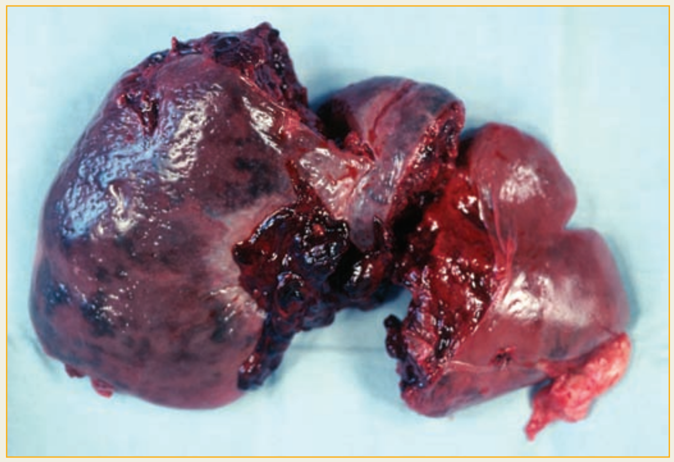


Figure 17-1 Traumatic injury occurs when the body's tissues are exposed to energy levels beyond their tolerance. Some traumatic injuries may not be visible. This photo shows a ruptured spleen.

You are the Paramedic Part 1

You are dispatched to 1601 South Main Street for "man fallen from a roof." This address is located in the business district of your service area. En route to the call, you learn that this man had been running from police and had come from a building in the downtown area. The patient is in police custody, and the scene is considered safe.

You arrive but are unable to assess much because the patient is combative and unwilling to answer your questions. You can see that his skin is slightly moist and a bit pale.

Initial Assessment	Recording Time: 0 Minutes
Appearance	Grimacing, screaming, punching
Level of consciousness	A (Alert to person, place, and day)
Airway	Patent
Breathing	Rapid and deep
Circulation	Unable to assess due to patient combativeness

1. What initial information about the fall gives rise for concern?
2. How does knowing your primary service area impact your understanding of potential patient injuries?
3. Given the location, what other conditions are you worried about?

(potential energy—a concrete bridge abutment). Kinetic energy would be found in two moving vehicles colliding. Potential energy would be present in a fall from a height. In that case, gravity would be the *potential* source of energy that can cause the object to fall. Chemical energy can be found in an explosive or an acid or even from a reaction to an ingested or medically delivered agent or drug. Electrical energy comes in the form of high voltage electrocution or a lightning strike. Barometric energy can result from sudden and radical changes in pressure, often occurring during diving or flying.

Biomechanics is the study of the physiology and mechanics of a living organism using the tools of mechanical engineering. Biomechanics provides a way of analyzing the mechanisms and results of trauma sustained by the human body. Kinetics studies the relationships among speed, mass, direction of the force, and, for paramedics, the physical injury caused by speed, mass, and force. Knowledge of kinetics can help you predict injury patterns found in a patient.

Factors Affecting Types of Injury

The kind of injury resulting after trauma is sustained will be determined by the ability of the patient's body to disperse the energy delivered by the traumatic event. Some patients' bodies can stretch and bend to absorb the energy of the traumatic event. But other patients' bone and tissue cannot absorb the energy. For example, a healthy football player can absorb a "hit" on the playing field better than an older man with diminished bone mass.

External factors that determine types of injury include the amount of *force* and *energy* delivered. The amount of injury (force) your patient sustains varies with the size (or mass) of the object delivering the force and energy, with the change in velocity (how fast your patient or the object is travelling), with acceleration or deceleration (how much the object or your patient speeds up or slows down), and with the body area to which the force is applied. This is a real world application of Newton's second law of motion (force = mass × acceleration). The primary reasons for the extent of trauma your patients sustain are the amount of energy in the object and the mechanism by which the object is delivered to the body. The body receives wider-spread trauma from a cannon ball (more energy inside) than it does from a bullet, although both are often lethal.

Duration and *direction* of the force of application are also important. The *rate of force application* affects trauma because energy that is applied rapidly is not tolerated as well as a similar amount of energy delivered over a longer period. For example, energy delivered rapidly can cause broken wrists, whereas longer-term energy delivery might show up as a repetitive stress injury—even though the amount of force might ultimately be exactly the same. In vehicle collisions, paramedics learn to recognize the directional patterns in injuries from front-end, side, and rear-end collisions.

The larger the area of force dissipation, the more pressure is reduced to a specific spot on the body, often without making a visible cut. Bullet impact is less if the energy in the bullet is dissipated over the ceramic plate inside a bulletproof vest than if all the force of the bullet is applied at a small location on the skin.

In trauma medicine, this spreading of impact is described as *blunt trauma*. Paramedics at all levels quickly learn in the prehospital environment that blunt trauma is difficult to diagnose because there is often little external damage. Paramedics study kinetics to help them diagnose this potentially lethal, but sometimes invisible, form of trauma.

At the Scene

Suspect a spinal injury when you see a cracked windshield, steering wheel or dashboard damage, intrusion into a vehicle, or fractured feet or ankles after a fall. It will make a difference in how you handle the ABCs.

The position of the trauma victim—how he or she is positioned—at the time of the event is an external factor. Seatbelts have done a great deal to effect the reduction in lethal injuries by keeping occupants in positions less likely to cause fatal injuries.

Internal injuries sustained when the break point of an organ is exceeded can be difficult to diagnose. There may be external markers, such as contusions, abrasions, lacerations, and punctures.

The *impact resistance of body parts* will also have a bearing on types of tissue disruption. Impact resistance is often determined by what is inside your patient's organs: gas, liquid, or solid.

Paramedics need to know that organs that have gas inside, such as in the lungs and intestinal tract, will scatter energy more than liquid or solid boundaries. This means that the organ around the gas will be easily compressed, so look for lung and intestinal trauma first. Water-bearing organs include the vascular system, the liver, spleen, and muscle. Water-bearing tissues are less compressible than gas-containing tissues. Solid density interfaces occur mostly in bones such as in the cranium, spine, and long bones.

Because many injuries are not obvious on first presentation, understanding the effects of forces and energy transfer patterns will help in the assessment of the *mechanism of injury* (MOI), which in turn can help predict the most likely type of injuries you will see when you are in the out-of-hospital setting Figure 17-2 ▶. Paramedic students need to learn to have a *high index of suspicion* for injuries that otherwise might be undetected for several hours. Anticipate the possibility of specific types of injury: you will help your patient and the trauma team who will need your assessment of the scene.

Trauma Centres

Paramedics need a good working knowledge of the hospital resources with a reasonable idea of how long transport will take. Frequently, you will be the decision maker about where

Figure 17-2 The appearance of the car can provide you with critical information about the severity of the collision and the possible injuries to the occupants.

Documentation and Communication

So much emphasis is placed on the MOI because obtaining a complete and accurate history of the incident can help predict as many as 95% of the injuries present. After ensuring your personal safety and maintaining the ABCs, the mechanism of injury is key information to obtain from the trauma scene. You must report the MOIs to the receiving trauma centre or emergency department. You are the eyes and ears of the trauma team at the scene of the injury.

your patient should be transported. Before you even get to the scene, you should know what is available in your area.

The Committee on Trauma (COT) of the American College of Surgeons is the governing body responsible for the designation of trauma centres in the United States. There are four separate categories of verification in the COT's program (Level I, II, III, and IV).

The Trauma Association of Canada (TAC) has developed similar guidelines for the organization and staffing of tertiary, district, and rural centres. Tertiary care centres in Canada are approximately equivalent to a Level I trauma centre as described by the American College of Surgeons.

Tertiary Trauma Centre (Level I)

- Plays the leading role within the regional or community trauma system. It has the capability of providing definitive care for seriously injured patients. The centre assumes the leadership role in the delivery of optimal care to the injured patient, research, teaching, data collection, evaluation, and the injury control and prevention program.
- Serves as a facility for the resuscitation of acutely injured patients, as well as the regional referral centre for severely injured patients. The centre must have a comprehensive external disaster response plan.
- Participates in research at the clinical and/or basic science level and in the management activities related to trauma care.
- Undertakes educational activities including the teaching of undergraduate and postgraduate physicians, as well as other allied health professionals. Teaching also includes outreach education throughout the region and public educational programs.
- Collects, analyzes, and produces reports on data, and participates in a provincial trauma registry. Participates in epidemiological studies of injury.
- Provides leadership in injury control and prevention programs, including identification of prevention priorities and strategies.
- Identifies the need for new resources.

District Trauma Centre (Level II)

- May be an urban hospital or rural community hospital.
- Is a strategically located centre with resources, human and physical, sufficient to treat single system injuries, some multisystem injuries, and fulfill resuscitation requirements prior to referral to a tertiary care centre.

Primary Trauma Centre (Level III)

- Is a smaller, general practitioner hospital or nursing station that serves as an initial "clearing station" and refers all but minor injuries to either its district trauma centre or to a tertiary trauma centre, following appropriate consultation.

Currently, there are 15 accredited Tertiary Trauma Centres in Canada. In some provinces, "trauma networks" have been established, with a lead trauma hospital providing Level I care.

Criteria for Referral to a Trauma Centre

Paramedics are responsible for determining whether a patient should go to a trauma centre—and at what level. In all provinces, trauma centres have been created in large urban centres and bypass and triage criteria have been established. You may also have to determine whether air transport is required to a tertiary or lead trauma centre. *The criteria for transport to a trauma centre vary from system to system.* Every paramedic should know his or her local and regional protocols for triage and bypass to a trauma centre. In January 2009, the US Centers for Disease Control and Prevention released their Guidelines for Field Triage of Injured Patients, derived from recommendations of a national expert panel. The guidelines state that patients meeting one of the following criteria should be preferentially transported to a designated trauma centre:

1. If one of the following is present, the patient should be referred to a trauma centre:
   - GCS (Glasgow Coma Scale score) < 14
   - RR (respiratory rate) < 10 or > 29
   - SBP (systolic blood pressure) < 90
   - RTS (revised trauma score) < 11
   - PTS (pediatric trauma score) < 9

At the Scene

The Canadian National Trauma Registry, maintained by TAC and the Canadian Institute for Health Information (CIHI) is a reporting system designed to collect trauma-related data in an effort to improve the quality and cost-effectiveness of care and to aid in outcome research. Your contribution as a paramedic is the record of what you found at the scene.

2. If one of the following is diagnosed in the prehospital environment, the trauma centre is a more appropriate triage endpoint:
   - Flail chest
   - Two or more proximal long bone fractures
   - Amputation proximal to wrist or ankle
   - All penetrating trauma to head, neck, torso, or extremities proximal to elbow or knee
   - Any limb paralysis
   - Pelvic fractures
   - Combination of trauma with burns
   - Open and depressed skull fractures
   - Major burns
3. Evaluate at this point the MOI and examine the trauma scene for evidence of high-energy trauma. If one of the following is present, refer to a trauma centre:
   - Ejection from vehicle
   - Death in same passenger compartment
   - Pedestrian thrown or run over or vehicle–pedestrian injury at > 8 km/h
   - Initial speed > 65 km/h
   - High-speed motor vehicle collision (> 65 km/h)
   - Intrusion into passenger compartment of > 30 cm
   - Major vehicle deformity > 50 cm
   - Extrication time > 20 minutes
   - Falls > 6 m
   - Rollover (unrestrained passenger)
   - Motorcycle collision at > 35 km/h or with separation of rider and bike
4. If none of the above criteria is met, then consider transfer to trauma centre if:
   - Patient of age < 5 or > 55 years
   - Pregnancy > 20 weeks
   - Known immunosuppressed patients
   - Known cardiac disease or respiratory disease comorbidity
   - Type 1 diabetes, cirrhosis, morbid obesity, or coagulopathy

At the Scene

In addition to being trauma centres, some hospitals specialize in spinal injury, burns, pediatric trauma, cardiac care (centres for heart transplantation, coronary catheter labs), microsurgery (hand and limb reimplantation), or hyperbaric therapy. Knowledge of local centres of expertise will help you make important decisions about your patient's care and destination.

The prehospital assessment of trauma patients is key to their management and transport to the appropriate definitive care facility.

Transport Considerations

When making a decision to transport a patient, several options must be considered. What are the needs of the patient? What is the level of the receiving facility? The patient should be transported to the closest, most appropriate facility to receive optimal care. You must also decide on the mode of transport that will offer the greatest benefit. Should you call for air transport, or is ground transport sufficient?

When making the decision to transport by ground, several factors should be taken into consideration. Can the appropriate facility be reached within a reasonable timeframe by ground? What is the extent of injuries? If in a congested area, can the patient be transported to a more accessible landing zone for air medical transport?

Air transport must be considered in several situations: (1) when there is extended transport time by ground, (2) when there are multiple casualties, (3) when extrication times are prolonged and patients are critically injured, and (4) when there are long distances to an appropriate facility as opposed to the closest emergency department. There also may be other times that air transport is appropriate Figure 17-3. If the patient can be transported to definitive care within a reasonable amount of time by ground, there is no need to call for air transport. Take into consideration the time it will take for the aircraft to lift off, travel, and land, just to reach the scene. By weighing the timeframe against transport by ground, you will be able to make an informed decision. Also take into account the terrain. Is there a safe area for landing? If not, how far will the patient need to be transported to reach a secure landing zone? If there is a great distance, ground transport may be a more reasonable option. Once the decision is made to call for

Figure 17-3 A helicopter may be used to transport patients quickly to the proper trauma centre.

air medical transport, contact your dispatcher to request a unit, or follow local protocols regarding contacting air support.

Helicopter Triage Criteria

All levels of prehospital paramedics should recognize the need for and criteria used in making the decision to use aeromedical transport in their service area. The key to success is recognizing the need for the aeromedical transport of patients and activating the service as early as possible. The trauma triage guidelines in this chapter should be used as a guideline, but providers must know their local and regional criteria for activation of a helicopter EMS response for trauma patients.

At the Scene

The Platinum Ten Minutes refers to the goal of the maximum time spent at a scene for a critical trauma patient. Scene times should be limited as much as possible to get the patient to more definitive care at a trauma centre. *Trauma*, more often than not, means that onsite stabilization is a questionable paramedic procedure. However, *other problems* may be better handled by onsite paramedic stabilization. One of your major tasks as a student paramedic is to *learn the difference* between the two.

A Little Physics

Although drivers of motor vehicles might not obey the community's traffic laws, they must—whether they want to or not—obey the laws of physics that govern all objects on our planet. A little familiarity with these laws will help you understand more about the mechanisms of trauma.

Velocity (V) is the distance an object travels per unit time. The difference between velocity and speed is that velocity is also defined by moving in a specific direction. Acceleration (a) of an object is the rate of change of velocity that an object is subjected to, whether speeding up or slowing down. Gravity (g) is the downward acceleration that is imparted to any object on earth by the effect of the earth's mass. During each second of a fall, the velocity or speed of the falling object increases by 9.8 m/sec^2.

Controversies

Some situations may have contraindications or relative contraindications for aeromedical transport. These situations include traumatic cardiac arrest, inclement weather conditions, extremely combative patients, morbidly obese patients, patients with barotrauma (diving injuries may necessitate lower flying altitudes), and situations in which ground transport and appropriate level of care are available and would permit quicker care.

The kinetic energy (KE) of an object is the energy associated with that object in motion. It reflects the relationship between the weight (mass) of the object and the velocity at which it is travelling and is expressed mathematically as:

$$\text{Kinetic energy} = \frac{\text{Mass}}{2} \times \text{Velocity}^2$$

$$\text{or, KE} = \frac{m}{2} \times v^2$$

You are the Paramedic Part 2

The police officers advise you that the patient was probably under the influence of PCP (phencyclidine hydrochloride), and in his attempts to avoid arrest, he climbed up a fire escape and fell. He landed on his hands and feet, stumbled for a few steps, and continued to try to run away unsuccessfully.

Vital Signs	Recording Time: 5 Minutes
Level of consciousness	V (Responsive to verbal stimuli)
Skin	Slightly moist, slightly pale, and cool
Pulse	Carotid (unable to access radial pulses because patient is being restrained); rapid (142 beats/min)
Blood pressure	168 by palpation
Respirations	60 breaths/min
Sa_{O_2}	99% while breathing room air

4. Given commonalities of fire escape locations, what other information do you have?
5. How does your patient's condition hinder your assessment techniques?
6. How do you compensate for this hindrance?

Thus, velocity has a much greater effect on KE than weight because it is squared Figure 17-4.

In other words, an object increases its kinetic energy more by increasing its velocity than by increasing its mass. The kinetic energy of an object involved in a collision must be *dissipated* as the object comes to rest. The kinetic energy of a car in motion that stops suddenly must be somewhere Figure 17-5. In a car, kinetic energy can be dissipated by braking, transforming to heat (another form of energy). If all the energy is not transformed into heat, however, the KE is transformed into deformed metal (potential energy), which results in damage to the car and its occupants. The mechanics of dissipation can result in injury. For example, a car travelling at 56 km/h hits a wall, which stops the car, but the driver is still travelling at 56 km/h until stopped by the seatbelts or the air bag, or, if not wearing a seatbelt, the steering wheel, dashboard, or windshield.

Speed kills exponentially: look what happens when velocity increases 10 km/h versus when the person weighs in at 10 kg heavier.

- 70 kg person at 10 km/h = 3,500 KE units
- 70 kg person at 20 km/h = 28,000 KE units
- 70 kg person at 30 km/h = 63,000 KE units
- 70 kg person at 40 km/h = 112,000 KE units
- 80 kg person at 40 km/h = 128,000 KE units
- 70 kg person at 55 km/h = 211,750 KE units
- 70 kg person at 65 km/h = 295,750 KE units

Note that when weight increases by 10 kg but velocity remains the same, there is not much change in the kinetic energy. However, when the velocity increases from 55 to 65 km/h (a difference of only 10 km/h), the KE (remember, that's energy in motion!) increases by 90,000 KE units!

Figure 17-4

Figure 17-5 The kinetic energy of a speeding car is converted into the work of stopping the car, usually by crushing the car's exterior.

Modern cars are designed to have crumple zones to maximize the amount of energy dissipated by deformation before the passenger compartment is involved. Because the vehicle damage so often shows just how fast the car was going, the amount of damage provides information to help in your decision about transferring your patient to a trauma centre.

In addition to the velocity at which the car (and its passengers) are travelling, the vehicle's angle of impact (front collision versus side impact, or how your patient hit the inside of a vehicle), the differences in the sizes of the two vehicles, and the restraint status and protective gear of the occupants will affect the amount of energy dissipation that affects your patients in a collision.

Remember the laws of physics that no driver can break? Here's a quick review. The law of conservation of energy states that energy can be neither created nor destroyed, it can only change form. Energy generated from a sudden stop or start must be transformed to one of the following energy forms: thermal, electrical, chemical, radiant, or mechanical (as discussed earlier).

Energy dissipation, as you know, is the process by which KE is transformed into one of these forms of mechanical energy. When a car stops slowly, its KE is converted to thermal energy—heat—by friction of the braking action. If the car wrecks, KE is also dissipated into mechanical energy as the car body crumples in a collision. Mechanical energy is further dissipated in the form of injury as the occupants sustain fractures or other bodily harm.

Protective devices such as seatbelts, air bags, and helmets are designed to *manipulate* the way in which energy is dissipated into injury. For example, a seatbelt converts kinetic energy of the occupants into a seatbelt–to-body pressure force rather than into a steering wheel deformation against the torso or a windshield shattering against the head.

Newton's first law of motion states that a body at rest will remain at rest unless acted on by an outside force. Similarly, a body in motion tends to remain in motion at a constant velocity, travelling in a straight line, unless acted on by an outside force. Most bodies in motion (without the assistance of a motor or other propulsion device) tend to eventually stop owing to the action of forces of friction, wind resistance, or other force resulting in deceleration.

Newton's second law of motion states that the force that an object can exert is the product of its mass times its acceleration:

Force = Mass (Weight) × Acceleration (or Deceleration)

The higher an object's mass and acceleration, the higher the *force* that needs to be applied to make a change of course or stop the object. Remember our cartoon? Force equals mass × acceleration or deceleration. Deceleration is slowing to a stop. Rapid deceleration, as may occur in a collision, dissipates tremendous forces and, therefore, major injuries. Deceleration and acceleration can also be measured in numbers of g forces. One g force is the normal acceleration of gravity. A two or three g acceleration or deceleration force is, logically enough, two or three times the force associated with the acceleration of gravity. A two g deceleration would make you feel like you are twice as heavy as you are at rest. Three g acceleration would make you feel three times heavier. High-speed collisions can generate decelerations in *hundreds* of g's. The human limit to deceleration is about 30 *g*.

In a *head-on collision* with two vehicles travelling in opposite directions along a straight line, transferred energy is represented in part as the sum of both their speeds. If a car strikes an immovable object, forces generated come from the speed of the only moving object. In a *rear impact* of two vehicles travelling along the same line, the energy potential is lessened because it is the difference in speed between them, also known as the *closing speed*.

It is important to have an understanding of these laws of physics because they help define the types and patterns of trauma you will see in the prehospital environment. You are the most important witness the hospital trauma team has—the information you learn from physics will affect the outcome of your patient's life.

Types of Trauma

Injuries are generally described as the consequence of blunt or penetrating trauma. Blunt trauma refers to injuries in which the tissues are not penetrated by an external object (Figure 17-6). Blunt trauma commonly occurs in motor vehicle collisions, in pedestrians hit by a vehicle, in motorcycle collisions, in falls from heights, in serious sports injures, and in blasts when no shrapnel is involved and the pressure wave is the primary cause of the injuries.

Penetrating trauma results when tissues are penetrated by single or multiple objects (Figure 17-7). Penetrating trauma results from gunshot wounds caused by a single or multiple projectiles, stab wounds, and blasts with shrapnel or secondary projectiles. Penetrating trauma may also occur in combination with blunt injuries such as in implement injuries during a motor vehicle collision or a fall out of a tree and onto a fence.

At the Scene

As a general rule, the entrance wound is smaller than the exit wound. Assume that cavitation involves internal structures that are not readily visible on your clinical examination.

Figure 17-6 Blunt trauma typically occurs in motor vehicle collisions.

Figure 17-7 Injuries from low-energy penetrations, such as a stab wound, are caused by the sharp edges of the object moving through the body.

Injuries Caused by Deceleration

Abrupt deceleration injuries are produced by a sudden stop of a body's forward motion. Whether from a fall, shaking a baby, or a high-speed vehicle collision, decelerating forces can induce shearing, avulsing, or rupturing of organs and their restraining fascia, vasculature, nerves, and other soft tissues. These injuries are often invisible during examination, so every paramedic needs to understand how such injuries are sustained.

The head is particularly vulnerable to deceleration injuries. The brain is a fairly heavy organ that lies in fluid inside the skull. Any trauma that will jerk the patient's head causes the brain to hit the inside of the skull, causing bleeding, bruising, tearing, and crush injuries. All of these injuries are extremely dangerous and might not show up on a cursory examination. Your paramedic index of suspicion should be on high alert for these injuries.

The chest is vulnerable to aorta injury. The *aorta,* the largest blood vessel in the body, is the most common site of deceleration injury in the chest. The aorta is often torn away from its points of fixation in the body. Shearing of the aorta can result in rapid loss of all the body's blood and immediate death.

Abdominal blunt trauma results as the forward motion of the body stops and internal organs continue their forward motion, resulting in tearing at their points of attachment and shearing injuries. Organs that can be affected include the liver, kidneys, small intestine, large intestine, pancreas, and spleen.

Kidneys are injured as forward motion produces tears to the organ or to points of attachment through the renal arteries. Also, as forward motion is restrained by the large bowel, the small bowel can tear and result in free air in the abdomen. Trauma can also do damage without tearing by causing an insufficient supply of blood to the bowel. The spleen can also be torn, sometimes resulting in left upper quadrant pain and life-threatening internal bleeding.

Injuries Caused by External Forces

Crush and compression injuries are the result of forces applied to the body by things external to the body at the time of impact. Crush and compression injuries occur *at* the time of impact, unlike deceleration injuries, which occur *before* impact. Crush and compression injuries are often caused by dashboards, windshields, the floor, and heavy objects falling on the body.

Compression head injuries, which may result in skull fractures, often are associated with cervical spine injury. The more severe the head injury, the more likely a cervical spine injury has also occurred. Brain tissue does not compress; it swells within the enclosed area of the skull. As the brain swells inside the skull, it is crushed, causing a catastrophic injury.

Compression injuries of the chest may produce *fractured ribs,* which can lead to internal injuries of the lungs and heart. One of the signs of a lung injury is a *flail chest,* a condition in which a section of the chest wall moves paradoxically with respirations (moves opposite of normal). Fractured ribs may also cause blood or air to seep into the chest space, which would require decompression and placement of a chest tube. Blunt cardiac injury can compress the heart against the chest wall, causing arrhythmias and direct injury to the heart muscle. If the lungs are compressed, acute respiratory distress syndrome (ARDS) can require intubation to maintain your patient's breathing.

Almost all abdominal organs can be affected by hitting an external object. Organs often injured are the pancreas, spleen, liver, and kidneys. Compression against the seatbelt may result in *bowel rupture, bladder rupture, diaphragm tearing,* and *spinal injuries*. The aorta continues from the chest down into the abdomen, where it can be involved in vascular injury.

You are the Paramedic Part 3

The police officers restrain the patient so that you can perform your initial assessment and a rapid trauma assessment, while taking spinal precautions. You are able to apply a cervical collar and minimize his movement on a backboard. During your rapid trauma assessment, you find that he has deformity of both legs below the knees. He also has some abrasions to both hands and arms. It appears as though the majority of force was absorbed by the legs during the fall.

Reassessment	Recording Time: 10 Minutes
Level of consciousness	V (Responsive to verbal stimuli)
Skin	Slightly moist, slightly pale, and cool
Pulse	Carotid (unable to access radial pulses as patient is being restrained); rapid
Blood pressure	168 by palpation
Respirations	60 breaths/min
Sao_2	98% while breathing room air; patient noncompliant with nonrebreathing mask

7. Given this information, what other injuries do you suspect?
8. How can a patient who is under the influence of drugs be difficult to manage?
9. In addition to trauma, what other medical emergencies can ensue from the use of PCP?

At the Scene

According to Transport Canada:

- 660,000 motor vehicle collisions occurred in 2003.
- Motor vehicle collisions were the cause of 2,766 fatalities in 2003.
- Fatalities and injuries have declined about 15% between 1994 and 2003, despite an increase in the number of registered motor vehicles.
- For the past 10 years, single-vehicle collisions have accounted for about 50% of all fatal collisions.
- Most deadly collisions occur on rural roads; 67% of fatal collisions took place on rural roads in 2003.
- Four out of five serious collisions occur in clear weather.
- The largest number of fatalities occurred in the 25- to 34-year age group. The second most at-risk age group was 65+ years.
- Of fatally injured drivers, 32% had a blood alcohol concentration over the legal limit of 17 mmol/l. In 1987, 47% of fatally injured drivers were legally intoxicated.
- 40% of vehicle occupants who died were not wearing seatbelts. 90% of Canadians regularly use seatbelts.
- Motor vehicle collisions accounted for 26,676 hospitalizations in 2004.
- Motor vehicle collisions accounted for just under one half of major injuries in Canada in 2004.
- 52% of fatalities were drivers.
- 23% of fatalities were passengers.
- 13% of injuries were pedestrians.
- Motorcyclists accounted for 1 in 16 of the total road fatalities in Canada.

Figure 17-8 Deceleration of the occupant starts during sudden braking and continues during impact and collision. The appearance of the interior of the car can provide you with information about the severity of the patient's injuries.

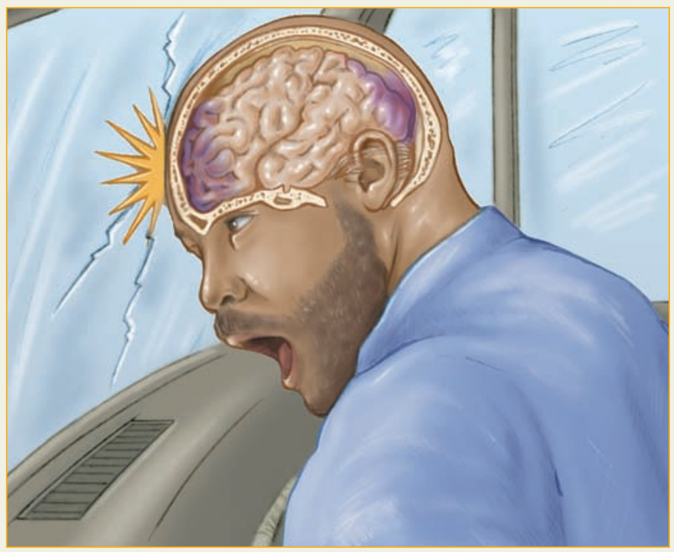


Figure 17-9 Deceleration of internal organs involves the body's supporting structures and movable organs that continue their forward momentum until stopped by anatomical restraints. In this illustration, the brain continues its forward motion and strikes the inside of the skull, resulting in a compression injury to the anterior portion of the brain and stretching of the posterior portion.

Pelvic fractures also result from external compressive trauma, potentially injuring the bladder, vagina, rectum, lumbar plexus, and pelvic floor and leading to severe bleeding from the large arteries near the hip bones.

Motor Vehicle Collisions

When a motor vehicle collides with another object, trauma in the collision is composed of *five phases* tied to the affects of progressive deceleration. The first phase, *deceleration of the vehicle,* occurs when the vehicle strikes another object and is brought to an abrupt stop. The forward motion of the car continues until its KE is dissipated in the form of mechanical deformation and damage to the vehicle and occupant or until the restraining force of the object is removed (for example, sheared off pole, yielding of a guard rail) and the vehicle motion continues until its KE is gently dissipated by drag or continued braking. The second phase is *deceleration of the occupant,* which starts during sudden braking and continues during impact and collision. This results in deceleration, compression, and shear trauma to the occupants **Figure 17-8 ▸**. The effects on vehicle occupants will vary depending on the mass of each occupant, protective mechanisms in the vehicle such as restraints and air bags, body parts involved, and points of impact. The third phase, *deceleration of internal organs,* involves the body's supporting structures (skull, sternum, ribs, spine, and pelvis) and movable organs (brain, heart, liver, spleen, kidneys, and intestine) that continue their forward momentum until stopped by anatomical restraints **Figure 17-9 ▴**. Energy is dissipated by internal organs as they are injured. Movement of fixed and nonfixed parts may result in tears and shearing injuries. The fourth phase is the result of *secondary collisions,* which occur when a vehicle occupant is hit by objects moving within the vehicle such as packages, animals, or other passengers. These objects may continue to travel at the vehicle's initial speed and then hit a passenger who has come to rest. These types of collisions have been known to cause severe spine and head trauma. The final phase is the result of *additional impacts* that the vehicle may receive, as when it is hit and deflected into another vehicle, tree, or another object. This may increase the seriousness of original injuries or cause further injury. For example, a frontal collision may cause a posterior hip dislocation and an acetabular fracture via a dashboard mechanism and a subsequent side impact from another vehicle may add a lateral compression pelvic ring injury, resulting in complex pelvic and acetabular trauma. Table 17-1 shows the structural clues, body clues, and resulting injuries for different types of collisions.

> **At the Scene**
>
> Don't forget that the collision of internal organs striking against the body can result in severe damage, though this may not always be obvious.

> **Notes from Nancy**
>
> When the windshield is cracked or broken, the front seat occupant has a cervical spine injury until proven otherwise.

Predicting Types of Injury by Examining the Scene

Important clues to predict injury types can be obtained by paying attention to the history of the collision and by an examination of the scene. Using your new-found knowledge of the physics of trauma, you can make a good estimate of how injured your patients might be by looking at the amount of damage around the scene. How dented and deformed the vehicle looks is a clear indication of the forces involved and of the degree of deceleration sustained by your patient. Dents and deformities on the inside of the vehicle will show you the point of impact on the patient. Do a quick check for injury types visible on your patient: head injury or seatbelt marks show what parts of the body may have been involved in energy absorption. Tire skid marks at the scene indicate whether significant energy was dissipated by braking before collision. Debris along the course of the collision may indicate multiple collisions and different force vectors acting on the patient along the course of the collision.

There are primarily *five types of impact patterns:* Frontal or head on, lateral or side impact, rear impact, rotational, and rollover. In *frontal and head-on collisions,* the front end of the car distorts as it dissipates kinetic energy and decelerates its forward motion. Passengers decelerate at the same rate as the vehicle. In a 45 km/h collision, the front end of an average car will crush 60 cm at the rough estimate of 1.5 cm of deformity for each 1 km/h. The forces applied to the driver will differ based on car design, materials, and safety features of the vehicle. The interior will also suggest possible injuries by the damage your patient's body has done to the dash, windshield, or steering wheel, for example.

Position at the precise time of impact is very important in determining an occupant's movements and injuries during a collision. Unrestrained occupants usually follow one of two trajectories, a *down-and-under pathway,* or an *up-and-over pathway.*

The down-and-under pathway is travelled by an occupant who slides under the steering column Figure 17-10. As the vehicle is decelerating, the occupant continues to travel downward and forward into the dashboard or steering column, led by the knees. The knees hit the dashboard, transmitting the energy of the deceleration up the femurs to the pelvis. With knees locked in the dash and hips in the seat, force vectors go down the tibia and along the femur. If the feet are not locked by folding floorboards or brake pedals, energy along the tibia will be transferred to the lower leg, with no immediate injury. If the feet are locked in place, midshaft femur fracture can occur. In some cases, the heads of the femurs will dislocate. If the occupant's knees hit the dashboard, look for a fracture-dislocation of the knee or for hip and pelvic fractures or hip dislocation. Your patient's torso can twist in such a way that his or her head hits the steering column. Always look for spinal injuries.

The upper torso continues forward until it impacts the car, be it the steering wheel or the seatbelt and air bag protection system. Look for rib fractures or pulmonary or cardiac injuries caused by internal striking and compressing. When your patient is a child, assume that there will be pulmonary or cardiac injuries—children have more flexible ribs but often sustain compression injuries. Remember how gas-containing organs absorb more of the energy of the collision?

> **Notes from Nancy**
>
> When there is damage to the steering assembly, there is critical injury to the driver until proven otherwise.

In the up-and-over pathway, the lead point is the head. In this sequence, rotation occurs around the ankles with the torso moving in an upward and forward direction. The head takes a higher trajectory, impacting the windshield, roof, mirror, or dashboard, causing compression and deceleration injuries in your patient that can include significant head and cervical spine trauma. The anterior part of the neck may strike the

Table 17-1 MOI: Motor Vehicle Collision

Structural Clues	Body Clues	Look for These Injuries
Head-on collision		
Deformed front end Cracked windshield	Bruised or lacerated head or face	• Brain injury • Scalp, facial cuts • Cervical spine injury • Tracheal injury
Deformed steering column	Bruised neck Bruised chest	• Sternal or rib fracture • Flail chest • Myocardial contusion • Pericardial tamponade • Pneumothorax or hemothorax • Exsanguination from aortic tear
Deformed dashboard	Bruised abdomen Bruised knee, misplaced kneecap	• Ruptured spleen, liver, bowel, diaphragm • Fractured patella • Dislocated knee • Femoral fracture • Dislocated hip
Lateral collision		
Deformed side of car	Bruised shoulder	• Clavicular fracture • Fractured humerus • Multiple rib fractures
Door smashed in	Bruised shoulder or pelvis	• Fractured hip • Fractured iliac wing • Fractured clavicle or ribs
"B" pillar deformed	Bruised temple	• Brain injury • Cervical spine fracture
Broken door or window handles	Bruised or deformed arms	• Contusions
Broken window glass	Dicing lacerations	• Multiple lacerations
Rear-end collision		
Posterior deformity of the vehicle Headrest not adjusted	Secondary anterior injuries, especially if the patient was unrestrained	• "Whiplash" injuries • Cervical spine fractures • Deceleration injuries of a head-on collision

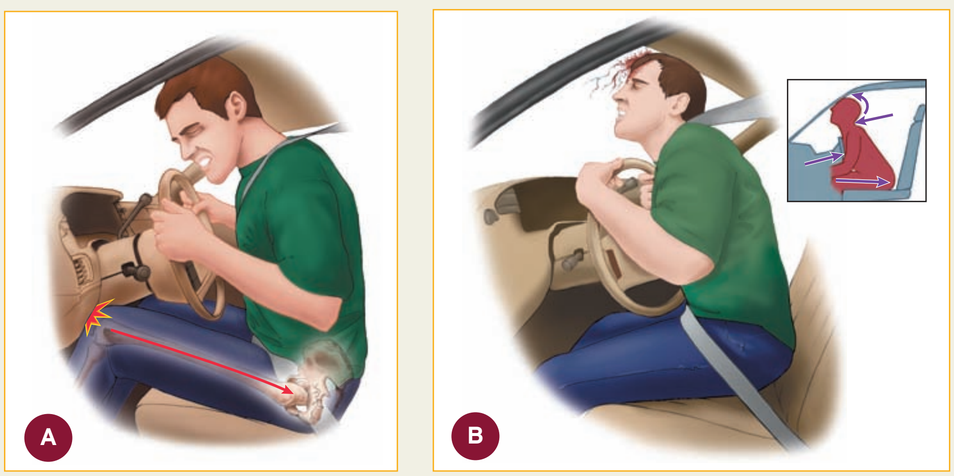


Figure 17-10 **A.** The down-and-under pathway. **B.** The up-and-over pathway.

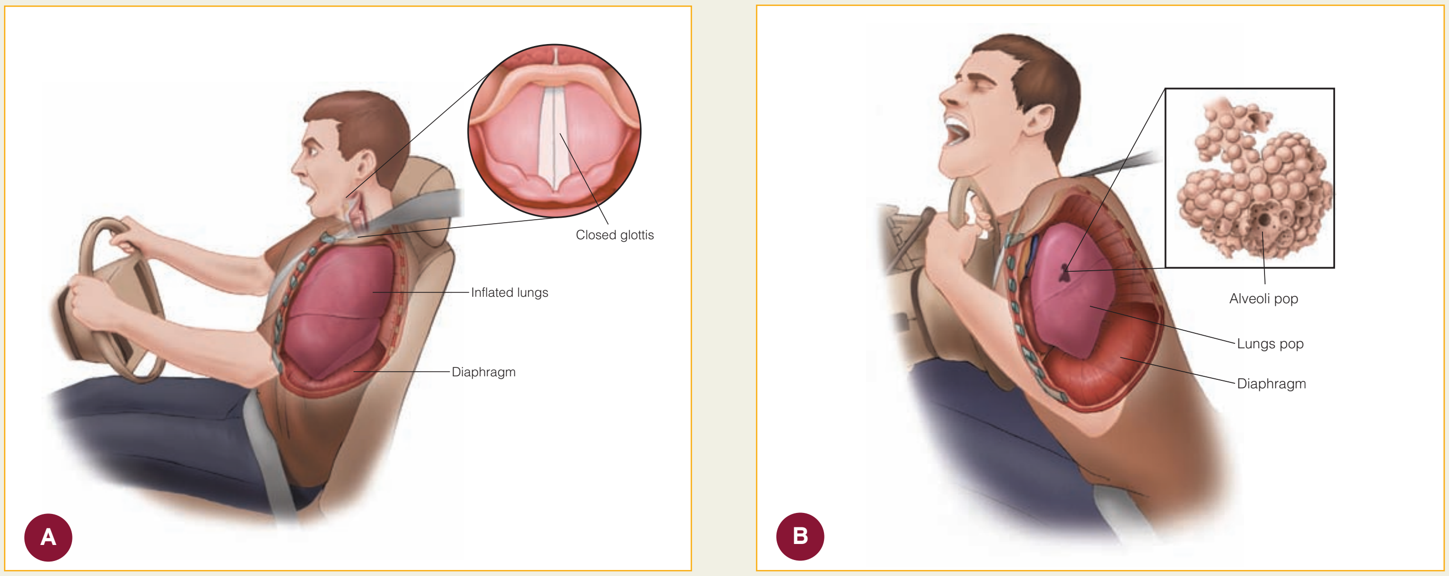
steering wheel, causing laryngeal fracture, serious lacerations, and other soft-tissue injury.

Ejection is possible if the windshield does not stop the body from projecting through it. This leads to second-impact injuries when the body contacts the ground or objects outside of the car. These injuries can be as severe as initial-impact injuries, and they increase the likelihood of great vessel damage and death. The spine absorbs energy as it is compressed between the stationary head and the moving torso, which leads to injury.

A dangerous lung injury may occur if your patient reflexively takes a deep breath just before impact, hyperinflating the lungs and closing the glottis. The impact of the steering wheel can injure the lungs via generation of pressures beyond the capabilities of lung tissue, like a "paper bag being exploded" (60% to 70% of pneumothoraces may occur this way) **Figure 17-11**.

The abdomen, pelvis, or upper thigh contacts the lower aspect of the steering wheel or dash, and lower leg fractures could be present. **Table 17-2** lists the "ring" of chest injuries that can occur from impacting the steering wheel or the dashboard.

Lateral impact, "T"-bone, and *side collisions* impart energy to the near-side occupant almost directly to the pelvis and chest **Figure 17-12**. Unrestrained occupants will remain almost motionless, literally having the car pushed out from under them. Seatbelts do little to protect these passengers because they are designed to limit forward hinging injuries, not side impacts. As one vehicle makes contact



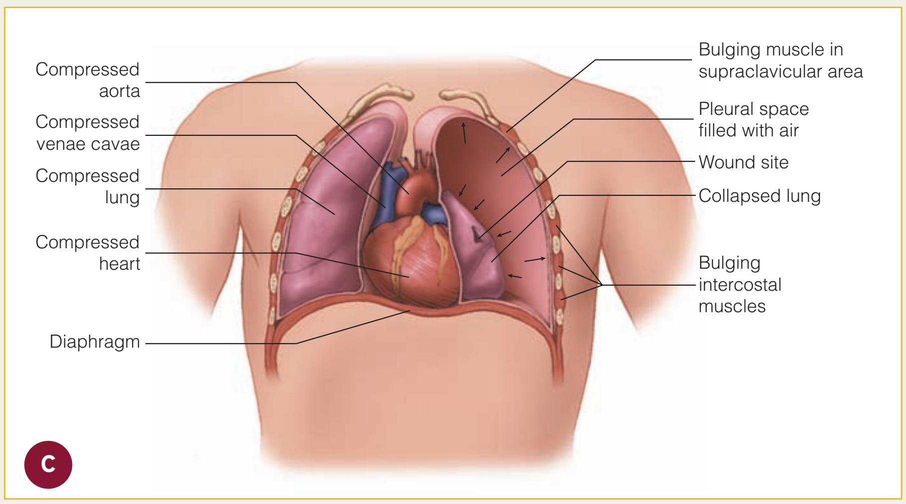


Figure 17-11 The paper-bag syndrome. **A.** The occupant takes a deep breath just before colliding, closing the glottis and filling the lungs with air. **B.** The occupant's chest hits the steering wheel, popping the alveoli in the lungs. **C.** A pneumothorax results.

Table 17-2	"Ring" of Chest Injuries From Impacting the Steering Wheel or Dashboard

- Facial injuries
- Soft-tissue neck trauma
- Larynx and tracheal trauma
- Fractured sternum
- Myocardial contusion
- Pericardial tamponade
- Pulmonary contusion
- Hemothorax, rib fractures
- Flail chest
- Ruptured aorta
- Intra-abdominal injuries

with the side of the other vehicle, the occupant nearest the impact is hit by the door of the car as the passenger compartment begins to deform and collapse. The head can strike the hood of the impacting vehicle or object. Injury results from direct trauma to the affected side and to tension

Figure 17-12 In a lateral collision, the car may be struck above its centre of gravity and begins to rock away from the side of impact. This causes a type of lateral whiplash in which the passenger's shoulders and head whip toward the intruding vehicle.

developed on the far side. Older vehicles may not have safety glass on the side windows. Upper extremity trauma depends on the spatial orientation of the arm at impact. The shoulder frequently rotates outward and posteriorly, exposing the chest and ribs to injury. Forces transmitted to the chest cause rib fractures, lateral flail chest, and lung contusions. If the humerus remains between the door and chest, the clavicle may absorb side motion and fracture. As the body of the occupant is pushed in one direction, the head moves toward the impacting object, creating a line of tension along the contralateral side. This may result in ligamentous disruption and dislocation of the spine on the opposite side of the impact. The far-side occupant, if properly restrained, has the advantage of "riding down" with the car, thereby receiving considerably less force. If unrestrained, he or she may move in a direction parallel but opposite to the impact. This passenger receives forces similar to any unrestrained occupant. Furthermore, because both passengers travel in a direction parallel to impact but in opposite directions, they collide with each other, causing additional injury.

In a lateral collision, if the greater trochanter of the femur is impacted and transmits forces to the pelvis, sometimes it may be driven through the acetabulum into the pelvis. If the force reaches the ilium, the pelvis may also fracture. The typical pattern of pelvic injury that occurs in this scenario is a lateral compression injury that trauma surgeons call pelvic ring disruption. Lateral compression injuries are less serious than anterior compression injuries. Death in lateral collisions is usually the result of associated torso or head injuries.

Rear-impact collisions have the most survivors, if the driver and passengers are properly restrained Figure 17-13. If the vehicle coming from the rear is travelling at excessive speed, however, most bets on survivability are off. Most often in this kind of collision, a stationary (or slower moving) vehicle is struck from behind and the impact energy is transmitted as a sudden forward accelerating force. The neck hyperextends as the body moves forward relative to the head. The head does not move forward with the body unless a headrest is in the proper position; if the headrest is not in proper position, the head is snapped back and then forward. Because most seats have some degree of elasticity after the sudden forward acceleration has ended, the stored potential energy in the seat is converted to an energy of forward motion, which can aggravate the hyperextension trauma to the neck and then follow with some rebound forward flexion of the head on the chest resulting in hyperflexion. A third episode of extension may occur as the chest moves forward. This is the so-called whiplash injury.

Figure 17-13 Rear-end impacts often cause whiplash-type injuries, particularly when the head and/or neck is not restrained by a headrest.

In a rear-impact collision, energy is imparted to the front vehicle, which accelerates rapidly, while frontal impact energy to the rear driver is reduced because energy is being transferred to the front car. One concern with rear-impact collisions is the frequency with which seat backs collapse, causing unrestrained occupants to be propelled into the back seat. Head restraints developed to prevent the head and torso from moving separately are not always adjusted correctly. Many are placed too low and act as a fulcrum that may actually facilitate the extension injury. They need to be adjusted so they are behind the head and not behind the neck.

A *rotational* or *quarter-panel impact* occurs when the collision is off centre. In this case, rotation occurs as part of the car continues to move and part of the car comes to a stop. The vehicle stops at the point of impact, but the opposite side continues in rotational motion around the impact point. The point of greatest speed loss of the vehicle is the site where the greatest damage to the occupant will occur. The resultant forces act along a vector oblique to the direction of travel. For example, in a ten o'clock impact with twelve o'clock being frontal, the driver would initially move forward and then diagonally as the vehicle rotates, striking the A pillar, the support for the windshield. The front-seat passenger would strike the rearview mirror area. The point of greatest deceleration becomes the location of the most severely injured patients. Occupants tend to receive a combination of frontal and lateral injuries. Because rigid objects may be in line with vector forces, head injuries may result. Three-point belts are effective in preventing injury in angled collisions of up to 45°.

Rollover scenarios have the greatest potential to cause lethal injuries. Injuries will be serious even if seatbelts are worn. However, if your patients did not wear seatbelts, they may be ejected, and they will have been struck hard with each change in direction the car makes with the rollover. Even a restrained occupant's head and neck will change direction with each change in the vehicle's position.

Ejection of the patient from the vehicle increases the chance of death by 25 times Figure 17-14. One of three ejected victims will sustain a cervical-spine fracture. A partial ejection can result in an arm or leg injured by being caught between the vehicle and the ground.

Figure 17-14 Occupants who have been ejected or partially ejected may have struck the interior of the car many times before ejection.

Restrained Versus Unrestrained Occupants

Seatbelts are highly effective because they stop the motion of any vehicle occupant who will otherwise travel at the same speed as the vehicle, until stopped. The seatbelt, although capable of delivering some injury at high speeds, will prevent the serious-to-fatal injuries of being unrestrained in the car and being ejected from the car. One of every 13 victims of ejection sustains major and permanent cervical spine damage. Restrained victims "ride down" the deceleration with belt elasticity and crush time of the car, with a nearly 45% reduction in fatalities. Restraints limit the contact of the occupants with the interior of the vehicle, prevent ejection, distribute deceleration energy over a greater surface, and prevent the occupants from violently contacting each other. As a result, all types of injuries are decreased, including head, facial, spine, thoracic, intra-abdominal, pelvic, and lower extremities, and ejection is also limited.

All arguments against seatbelt use are unfounded. Every unrestrained passenger poses a hazard to themselves and to other occupants in the vehicle, especially for front seat passengers who are at double risk for injury in a front-end collision if the back seat occupants are unrestrained.

Specific injuries associated with seatbelt use include cervical fractures due to flexion stresses and neck sprains due to deceleration and hyperextension. Most serious injuries occur because the patient did not use the seatbelt correctly. If the occupant does not use the lap strap, severe upper body injuries, including spinal injuries and decapitation, can occur. If the seatbelt is placed above the pelvic bone, abdominal injuries and lumbar spine injuries result.

Air bags were another great step up for patient safety. They have reduced deaths in direct frontal collisions by about 30%. Front air bags will not activate in side impact collisions or impacts to the front quarter panel, and without the use of a seatbelt, they are insufficient to prevent ejection. They are self-deflating and function only for a first impact, not the secondary ones. The rapidly inflating bag can also result in secondary injuries from direct contact with the air bag or from the chemicals used to inflate it. Common injuries include abrasions and burns to the face, chest, and arms; minor corrosive toxic effects, chemical keratitis, conjunctivitis, or corneal abrasion, and inhalation injuries Figure 17-15 ▾.

Small children can be severely injured or killed if air bags inflate while they are in the front seat. That is why all paramedics are encouraged to participate in teaching parents how to properly place and secure children's car seats.

Unique Patient Populations

Increased morbidity and mortality, especially chest trauma, is more common in *geriatric patients,* particularly rib and sternal fractures. Fatalities also increase if *child* restraint devices are improperly installed or used. Children who have outgrown a car seat but are too small to be restrained by belts designed for adults are at risk for hyperflexion and abdominal injury.

Special Considerations

The different mechanisms of injury in children and the unique anatomical features of children together produce predictable patterns of injury. Because penetrating injuries are uncommon and because the head (compared with the rest of the body) is larger in childhood, injured children often have blunt injuries primarily involving the head. If the energy impact is severe and involves the entire body, the child may have a pattern involving the head, chest, abdomen, and long bones.

Pregnant women in general wear seatbelts less frequently than do nonpregnant women owing to the unproven concern that the seatbelt may increase damage to the unborn child in the case of a collision. However, no study has reported that seatbelts increase

Figure 17-15 Air bags can cause abrasions to the face, chest, and arms.

fetal mortality. If lap belts are worn alone and too high, they allow enough forward flexion and subsequent compression to rupture the uterus because deceleration forces are transmitted directly to the uterus. Lap belts with shoulder harnesses are essential to provide equal distribution of forces and to prevent forward flexion of the mother. Without the shoulder harness, the protuberant uterus will also receive the impact of the steering wheel or dashboard. Steering wheel or dashboard injuries sustained because seatbelts were not worn or worn improperly are associated with a 50% fetal death rate.

Figure 17-16 At a motorcycle collision scene, attention should be given to the deformity of the motorcycle, the side of most damage, the distance of skid in the road, the deformity of stationary objects or other vehicles, and the extent and location of deformity in the helmet.

Motorcycle Collisions

In 2003, motorcycles made up only 1 of every 51 vehicles on the road. Despite this, motorcycles still accounted for 6.4% (177) of Canada's road user fatalities in 2003. Motorcycling deaths increased significantly in the 45- to 54-year age group from 1994 to 2003 and decreased slightly in most other age groups.

In a motorcycle collision, any structural protection afforded to the victims is not derived from a steel cage, as is the case in a car, but from protective devices worn by the rider, that is, helmet, leather or abrasion-resistant clothing, and boots. While helmets are designed to protect against impact forces to the head, they transmit any impact into the cervical spine, and as such, do not protect against severe cervical injury. Leather and synthetic gear worn over the body was initially designed to protect professional riders in competition, where falls tend to be controlled and result in long sliding mechanisms on hard surfaces rather than multiple collisions against road objects and other vehicles. Leather clothing will protect mostly against road abrasion but offers no protection against blunt trauma from secondary impacts. In a street accident, collisions occur usually against other larger vehicles or stationary objects.

When you are assessing the scene of a motorcycle collision, attention should be given to the deformity of the motorcycle, the side of most damage, the distance of skid in the road, the deformity of stationary objects or other vehicles, and the extent and location of deformity in the helmet **Figure 17-16 ▲**. These findings can be helpful in estimating the extent of trauma in a patient.

There are *four types of motorcycle impacts.* In a *head-on collision,* the motorcycle strikes another object and stops its forward motion while the rider and parts of the motorcycle that are broken off continue their forward motion until stopped by an outside force, such as drag from the road or another opposing force from a secondary collision. Because the motorcycle's centre of gravity is above the front axle, there is a forward and upward motion at the point of the collision, causing the rider to go over the handlebars. If the rider's feet remain on the pegs or pedals, the forward and upward motion of the upper torso is restrained by femurs and tibias, producing bilateral femur or tibia fractures and severe foot injuries.

For motorcycles with a low riding seat below the level of the gas tank, such as Japanese racing bikes or Italian transalpine style motorcycles, the tank can act as a wedge on the pelvis during the initial phase of the collision resulting in severe APC (anterior-posterior compression) injuries to the pelvis, often resulting in severe neurovascular compromise. Open pelvic fractures are also common, resulting in severe perineal injuries with loss of the pelvic floor. Mortality associated with open pelvic fractures approaches 50%.

In an *angular collision,* the motorcycle strikes an object or another vehicle at an angle so that the rider sustains direct crushing injuries to the lower extremity between the object and the motorcycle. This usually results in severe open and comminuted lower extremity injuries with severe neurovascular compromise, often requiring surgical amputation.

Special Considerations

Changes in vision, hearing, posture, and motor ability predispose older people to a greater risk of being struck by a vehicle.

Traumatic amputations are also common high-speed injuries. After the initial crush injury to the lower extremity, mechanisms such as those described in the head-on collision also apply. Often the rider is propelled over the hood of the colliding vehicle. Because the collision is at an angle, severe thoracoabdominal torsion and lateral bending spine injuries can result, in addition to head injury and pelvic trauma.

An *ejected* rider will travel at high speed until stopped by a stationary object, another vehicle, or by road drag. Severe abrasion injuries (road rash) down to bone can occur with drag. An unpredictable combination of blunt injuries can occur from secondary collisions.

A technique used to separate the rider from the body of the motorcycle and the object to be hit is referred to as *laying the bike down*. It was developed by motorcycle racers and adapted by street bikers as a means of achieving a controlled collision. As a collision approaches, the motorcycle is turned flat and tipped sideways at 90º to the direction of travel so that one leg is dropped to the grass or asphalt. This slows the occupant faster than the motorcycle, allowing for the rider to become separated from the motorcycle. If properly protected with leather or synthetic abrasion-resistant gear, injuries should be limited to those sustained by rolling over the pavement and any secondary collision that may occur. When executed properly, this maneuver prevents the rider from being trapped between the bike and the object. However, a rider unable to clear the bike will continue into the vehicle, often with devastating results.

With any type of collision, the helmet should remain on unless airway management techniques cannot be performed with the helmet in place or the helmet does not fit snuggly to the head. Dents and abrasions must be assumed to have caused c-spine fractures until proven otherwise by an x-ray. Precautions should be taken to remove the helmet, which should be cut if it cannot be removed without introducing further deformation to the neck.

Pedestrian Injuries

In 2003, 379 pedestrians were killed and 13,340 were injured in Canada. Canadian seniors over age 65 accounted for 31.4% of pedestrian fatalities, even though they comprise only 12.8% of the population. Approximately 50% of urban pedestrian fatalities occurred at intersections. In 2003, 44 deaths were a result of bicycles being hit by a vehicle.

More than 85% of pedestrians are struck by the vehicle's front end, sustaining a predictable pattern of injuries starting with those caused by direct impact with the bumper. Adult injuries are generally lateral and posterior because adults tend to turn to the side or away from impact, whereas children will face forward into the oncoming vehicle.

There are *three predominant mechanisms of injury*. When the vehicle strikes an adult body with its bumpers, it creates lower extremity injuries, particularly to the knee and leg. These are in the form of various patterns of tibia-fibula fractures, often open knee dislocations and tibial plateau fractures. Usually the tibia is fractured on the side of impact; the impact potentially fractures the other leg as well. Knee dislocations are common with severe multiligamentous injury.

In the prehospital environment, a dislocated knee should be splinted in the position found if the patient has good distal PMS—pulse, and motor and sensory function. It is key to remember that if the knee reduces spontaneously, you must communicate this to the trauma team verbally and in your report. Spontaneous reduction is an indication of possible vascular injury that can be missed by the trauma team if you do not report the spontaneous reduction.

A *second impact* occurs as the adult is thrown on the hood and/or grille, resulting in head, pelvis, chest, and coup-contrecoup traumatic brain injuries. Lateral compression pelvic fractures are common in this mechanism and can cause open fractures with bony punctures of the vagina in women and in other viscera. A *third impact* occurs when the body strikes the ground or some other object after it has been subjected to a sudden acceleration by the colliding vehicle.

Pediatric patterns of pedestrian injury are different from patterns in adults. Small children are shorter, so the car bumper is more likely to strike them in the pelvis or torso, causing severe injuries from direct impact Figure 17-17. Although they are less likely than adults to fly over the hood of the car, they are more likely to be run over by the vehicle as they are propelled to the ground by the impact. Multiple extremity and pelvic fractures and abdominal and thoracic crush injuries are to be expected. Closed head trauma often kills young patients.

The Waddell triad refers to the pattern of vehicle–pedestrian injuries in children and people of short stature: (1) The bumper hits the pelvis and femur instead of the knees and tibias. (2) The chest and abdomen hit the grille or low on the hood of the car (sternal and rib fractures). (3) The head strikes the vehicle and then the ground (skull and facial fractures, facial abrasions, and closed head injury).

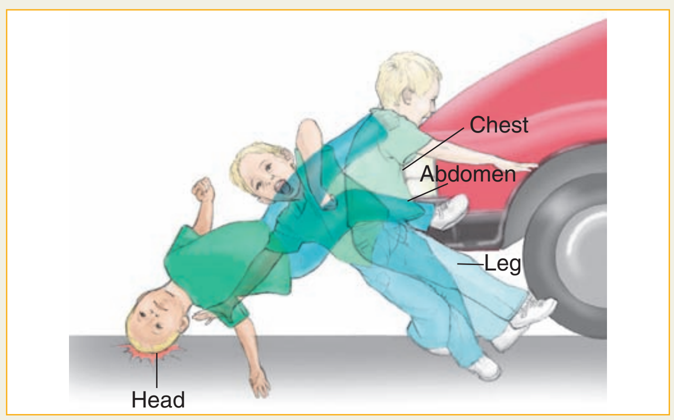


Figure 17-17 In car versus pedestrian collisions, children frequently sustain multisystem injuries involving the head, chest, abdomen, and long bones.

Falls From Heights

High falls most commonly involve children younger than 5 years of age who are left unsupervised near a high window (more than 3 m) or on a porch higher than 3 m with inadequate railings. Adult falls from heights usually occur in the context of criminal activity, attempted suicide, or intoxication such as in alcohol, narcotic, or hallucinogen use, especially PCP.

Remember that a fall produces acceleration downward at 9.8 m/sec^2. On contact with the floor or ground, an instantaneous deceleration occurs that decelerates the victim from whatever velocity had been achieved at the end of the fall to zero velocity. If a person falls for 2 seconds, the speed at impact is nearly 20 m/sec.

The severity of injuries you can expect to find in your patient will depend on a number of factors, all of which will be important in your patient assessment:

- **Height.** The height from which the patient has fallen will determine the *velocity* of the fall. A person falling one storey (3.5 m) onto concrete, for example, will fall at about 9 m/sec and experience an impact force of about 48 *g*. A person falling from the second storey (8 m) will reach a velocity of 14 m/sec and experience an impact force of 95 *g* on the same surface. Height plus stopping distance predicts the magnitude of deceleration forces. Assuming an average storey or floor is 3.5 m, a fall of four stories will kill 50% of those who fall. A fall of seven stories will kill 90% of those who fall.
- **Position.** The position or orientation of the body at the moment of impact will also be a determinant of type of injuries sustained and their survivability. Children tend to fall headfirst, owing to the relatively greater mass of a child's head, so head injuries are common in children, as are injuries to the wrists and upper extremities when the child attempts to break his fall with outstretched arms. Adults, on the other hand, usually try, when not intoxicated, to land on their feet, thus controlling their fall. However, they often tilt backward, landing on their buttocks and outstretched hands. The group of potential injuries from a vertical fall to a standing position is commonly referred to as the *Don Juan syndrome* or *lover's leap* pattern of injuries Figure 17-18. Injuries include foot and lower extremity fractures, along with hip, acetabular, and pelvic ring and sacral fractures. Lumbar spine axial loading also results in vertebral compression and burst fractures particularly of T12-L1 and L2. Vertical deceleration forces to organs (liver, spleen, and aorta) and fractures of the forearm and wrist (Colles' fracture) are also common.
- **Area.** The area over which the impact is distributed—the larger the area of contact at the time of impact, the greater the dissipation of the force and the lesser the peak pressures generated.
- **Surface.** The surface onto which the person has fallen and the degree to which that surface can deform (degree of plasticity) under the force of the falling body can help dissipate the forces of sudden deceleration. Deep snow, for example, has a relatively large capacity to deform, whereas concrete has scarcely any plasticity. Also, contrary to what may be expected, water also has very little plasticity at high-speed impacts. The surface of contact may also present hazards in the form of irregularities or protruding structures; it is far more dangerous to fall onto a wrought-iron picket fence, for example, than onto the grass beside it. If the surface does not conform, the unprotected body will.
- **Physical condition.** The physical condition of the patient in the form of preexisting medical conditions may also influence the injuries sustained. Most notably is the case of older patients with osteoporosis, a condition that predisposes to fractures even with minimal falls. Patients with hematologic conditions resulting in an enlarged spleen may also be more prone to a ruptured spleen in a fall. Children younger than 3 years of age have fewer injuries from falls greater than three stories than do older children and adults, most likely because of the more elastic nature of their tissues and less ossification.

Figure 17-18 When an adult jumps or falls and lands on his or her feet, the energy is transmitted to the spine, sometimes producing a spinal injury in addition to injuries to the legs and pelvis.

Penetrating Trauma

Unlike blunt trauma, which can involve a large surface area, penetrating trauma involves a disruption of the skin and underlying tissues in a small, focused area. Although a variety of objects may cause penetrating injuries in a variety of settings, penetrating trauma is usually interpreted as being more specific to injuries caused by firearms, knives, and other devices used as a means to cause intentional or accidental harm.

In Canada, the most common sources of penetrating injuries are firearms Figure 17-19. In 2002, 816 Canadians died from gun-related injuries. Deaths from firearms have fallen steadily from 1979 to 2002, mostly because of a decrease in gun-related suicides. In Canada, 80% of gun fatalities are suicides, 15% are homicides, and 4% are unintentional. Homicide deaths involving firearms also fell in Canada, falling from 0.8 deaths per 100,000 in the 1980s to 0.4 deaths per

Figure 17-19 Guns are a common cause of penetrating trauma, as shown in this case.

100,000 in 2002. Guns are used in about one third of homicide cases. In 2002, death rates from gun injuries were about the same in all age groups over 15 years.

The risk of dying from a firearms-related injury is significantly higher in the United States than in Canada. In 2000, American males were three times more likely to die from a gun injury than Canadian males. American females were seven times more likely to die from a gun injury. Gun-related deaths are also much higher, per capita, in the Northern territories than in the rest of Canada.

Stab Wounds

The severity of a stab wound depends on the anatomical area involved, depth of penetration, blade length, and angle of penetration. A stab wound may also involve a cutting- or hacking-type force such as in machete wounds, which not only can result in laceration, but also can cause fractures and blunt injury to underlying soft tissues and bone and potentially amputation.

Neck wounds can involve critical anatomical structures such as the carotid arteries, subclavian vessels, apices of the lung, the upper mediastinum, trachea, esophagus, and thoracic duct. Deep neck wounds of sufficient energy can result in spinal cord involvement and cervical fracture.

Lower chest or upper abdominal wounds have the potential of involving the thoracic and abdominal cavities, depending on the location of the diaphragm at the time of injury, that is, whether the person was taking a breath or exhaling.

Be careful when documenting the location, size, and nature of stab wounds, because your records may be used in criminal proceedings. The pattern of stab wounds closely relates to the mechanism of injury. Wounds delivered to the back are generally downward, whereas stab wounds from the front are generally upward, although this may be difficult to determine from inspecting the wound externally.

Gunshot Wounds

Firearms are the primary mechanism resulting in penetrating trauma. The amount of damage a firearm can cause will depend on a number of factors, including the type of firearm (rifle, shotgun, or handgun), velocity of the projectile, physical design of the projectile, the distance to the target from the muzzle of the firearm, and the type of tissue that is struck.

There are hundreds if not thousands of firearm models and designs. However, they can be classified primarily into three types: shotguns, rifles, and handguns.

Shotguns fire round pellets (referred to as "shot"), from about half a dozen to several dozen at a time, depending on the type of load used. The load denominated 00 or 000 "buckshot" is the larger pellets, and smaller shot such as No. 7 is a common fowl hunting shot or "birdshot." At short range, even the smaller shot can cause devastating injuries. Shotgun shells can also be loaded with a single large and heavy projectile called a sabot, which can cause even worse harm. A shotgun typically has a smooth bore, and its numerous projectiles are not stabilized in flight by spin, as is the single projectile fired from a

You are the Paramedic Part 4

After the patient is placed on the backboard, you decide to load the patient into the ambulance where you reattempt splinting of injured extremities, establish vascular access, and administer a 500-ml bolus of normal saline en route to the hospital. You alert the hospital staff of the need for security personnel on your arrival to the emergency department.

Reassessment	Recording Time: 15 Minutes
Level of consciousness	V (Responsive to verbal stimuli)
Skin	Slightly moist, slightly pale, and cool
Pulse	136 beats/min
Blood pressure	160/88 mm Hg
Respirations	34 breaths/min
Sa_{O_2}	98% while breathing room air; patient noncompliant with nonrebreathing mask
ECG	Sinus tachycardia with occasional unifocal premature ventricular contractions

10. What will remain a concern throughout this call?

rifle barrel. The pellets, therefore, leave the barrel and immediately start dispersing so that the shot density (that is, the separation between any two pellets) at the time of impact on a target will be determined by the distance travelled.

At very close range (less than 10 m), a shotgun can induce destructive injuries. Entrance and exit wounds can be very large, with shotgun wadding, bits of clothing, skin, and hair driven into the wound that can cause massive contamination, leading to increased infection potential should the patient survive the initial trauma.

Rifles are firearms firing a single projectile at very high velocity through a grooved barrel that imparts a spin to the projectile that stabilizes the projectile's flight for accuracy.

Handguns are of two types: revolvers and pistols. Revolvers have a cylinder holding from 6 to 10 rounds of ammunition, and pistols have a separate magazine holding as many as 17 rounds of ammunition in some models. Handguns also have rifled barrels to impart spin to a bullet, but their accuracy is more limited than a rifle's because their barrels (and sight radius) are shorter. The ammunition handguns fire is also, in general, less powerful than ammunition fired from rifles, and handguns fire at lower velocities.

The most important factor for the seriousness of a gunshot wound is the *type of tissue* through which the projectile passes. Tissue of high elasticity like muscle, for example, is better able to tolerate stretch (temporary cavitation) than tissue of low elasticity, like the liver. A high-velocity bullet fired through a fleshy part of the leg may do much less damage than a relatively low-velocity bullet that punctures the aorta or the liver. Many bullet wounds of the extremities that are found to have caused no fracture or neurovascular compromise will be treated by the trauma team with splinting and a single dose of antibiotic without a need for wound exploration or bullet retrieval.

An entry wound is characterized by the effects of initial contact and implosion. Skin and subcutaneous tissues are pushed in, cut, or abraded externally as missile fragments pass and heat is transferred to the tissues. At close range, tattoo marks from powder burns can occur. At extremely close ranges, burns can occur from muzzle blast. Heavy wound contamination results from negative pressure generated behind the travelling projectile, which sucks surrounding elements such as clothing into the wound, greatly increasing infection potential.

Deformation and tissue destruction sustained in soft tissues and bone is based on a combination of factors, including density, compressibility, missile velocity, and missile fragmentation. The initial path of tissue destruction is caused by the projectile crushing the tissue during penetration. This creates a permanent cavity that may be a straight line or an irregular pathway as the bullet is deflected into a number of angles after initial penetration. Pathway expansion refers to the tissue displacement that occurs as the result of low-displacement shock waves (sonic pressure waves) that travel at the speed of sound in tissue (four times the speed of sound in air). These shock waves push tissues in front of and lateral to the projectile and may not necessarily increase the wound size or cause permanent injury, but they result in cavitation (cavity formation). Tissue is compressed and accelerated away, causing injury. The waves of tissue are similar to throwing a rock into a pond. The rock creates a hole in the pond that quickly refills while waves emanate from the penetrating "wound," or hole in the pond.

Bowel, muscle, and lung are relatively elastic, resulting in fewer permanent effects of temporary cavitation. Liver, spleen, and brain are relatively inelastic, and the temporary cavity may become a permanent defect. Missile fragmentation is a major cause of tissue damage as the projectile sends off fragments that create their own separate paths through tissues. Secondary missiles can also be generated by pieces of bone, teeth, buttons, or other objects encountered in the projectile's path as it enters the body. Exit wounds occur when the projectile has sufficient energy that is not entirely dissipated along its trajectory through the body. The projectile then exits the patient and can injure other bystanders as well.

The size of the exit wound depends on the energy dissipated and the degree of cavitation at the point of exit. Exit wounds usually have irregular edges and may be larger than the entry wound **Figure 17-20**. There may be multiple exit wounds in the case of fragmentation. The number of exit wounds and the extent of tissue damage encountered must be assessed and carefully documented.

At the Scene

Don't assume that a bullet followed a straight path between the entrance and exit sites. It may ricochet inside the body, especially off bones, and travel in many different directions.

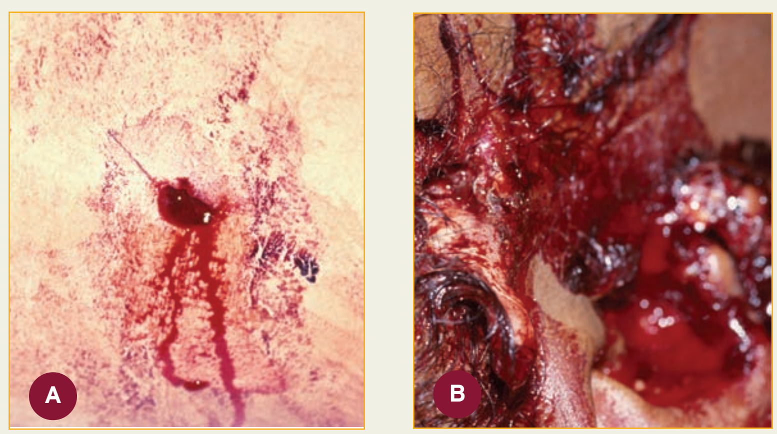


Figure 17-20 **A.** Entrance wound from a gunshot. **B.** Exit wound from a gunshot.

Shotgun wounds are the result of tissue impacted by numerous projectiles. As described earlier, the greater the distance from the muzzle to the target, the more dispersion the multiple projectiles will have and the more KE that will be lost before impact. Thus, shotguns are most lethal when used as short-range weapons. Also, the velocity of each pellet is less than the velocity of any bullet fired from a rifle.

Wounding potential from an injury sustained from a shotgun depends on the powder charge, the size and number of pellets, and the dispersion of the pellets. Dispersion is in turn determined by the range at which the weapon was fired, the barrel length (shorter barrels have more scatter), and the type of choke at the end of the barrel.

To give the trauma team at the hospital as much information as possible, try to obtain the following information:

- *What kind of weapon* was used (handgun, rifle, or shotgun; type and calibre, if known)?
- At *what range* was it fired?
- *What kind of bullet* was used? (Ideally, see if the police can find an unfired cartridge.)

What to look for:

- Powder residue around the wound
- Entrance and exit wounds (the exit wound is usually larger and more ragged)

In the real world, the assailant is usually gone, along with the weapon, and patient care is the first goal of paramedics, a far more pressing matter than obtaining answers to the previous questions. Be careful, again for legal reasons, when describing entry or exit wounds in your documentation. It may be better to simply describe the location(s) and/or shape(s) of wounds. Leave forensics to the experts.

Blast Injuries

Although most commonly associated with military conflict, blast injuries are also seen in civilian practice in mines, shipyards, chemical plants, and, increasingly, in association with terrorist activities. People who are injured in explosions may be injured by any of four different mechanisms Figure 17-21:

- **Primary blast injuries.** These are due entirely to the blast itself, that is, damage to the body caused by the pressure wave generated by the explosion.
- **Secondary blast injuries.** Damage results from being struck by flying debris, such as shrapnel from the device or from glass or splinters, that have been set in motion by the explosion. Objects are propelled by the force of the blast and strike the victim, causing injury. These objects can travel great distances and be propelled at tremendous speeds, up to nearly 5,000 km/h for conventional military explosives.
- **Tertiary blast injuries.** These occur when the patient is hurled by the force of the explosion against a stationary object. A "blast wind" also causes the patient's body to be hurled or thrown, causing further injury. In some cases, wind injuries can amputate limbs.
- **Miscellaneous blast injuries.** These include burns from hot gases or fires started by the blast, respiratory injury from inhaling toxic gases, and crush injury from the collapse of buildings, among others.

The vast majority of patients who survive an explosion will have some combination of the four types of injury mentioned. We will confine our discussion here to primary blast injuries because they are the most easily overlooked.

The Physics of an Explosion

When a substance is detonated, a solid or liquid is chemically converted into large volumes of gas under pressure with resultant energy release. Propellants, like gunpowder, are explosives designed to release energy relatively slowly compared with high explosives (for example, trinitrotoluene), which are designed to detonate very quickly. Composition C4 can create initial pressures of more than 27.5 million kilopascals ("4 million pounds per square inch"). This generates a pressure pulse in the shape of a spherical

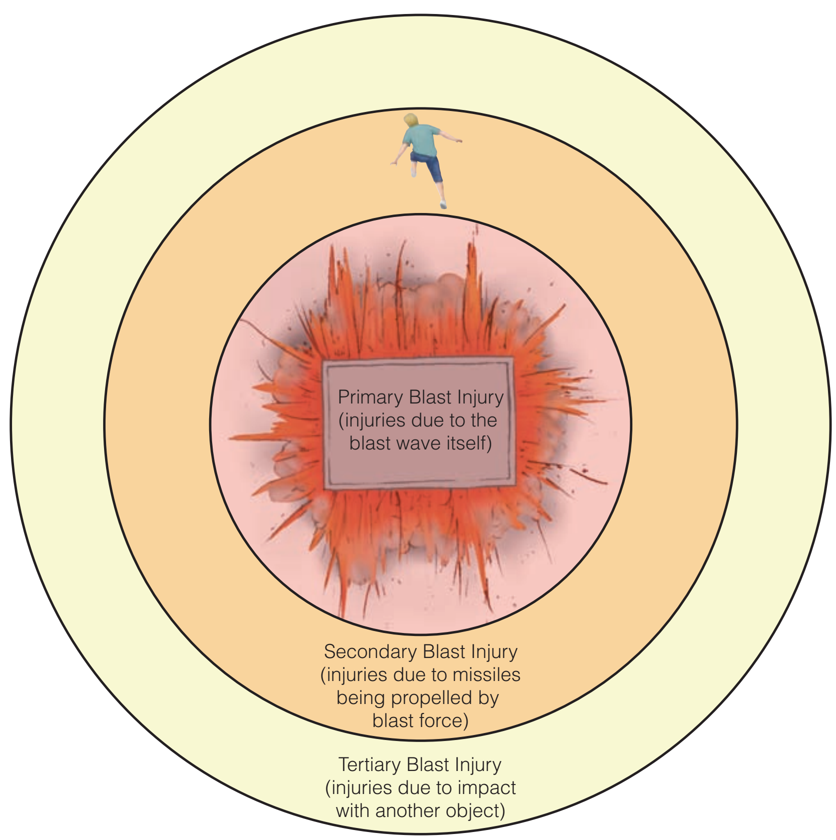


Figure 17-21 The mechanisms of blast injuries.

blast wave that expands in all directions from the point of explosion. Flying debris and high winds commonly cause conventional blunt and penetrating trauma.

Components of Blast Shock Wave

The leading edge of the shock wave is called the blast front. A positive wave pulse refers to the phase of the explosion in which there is a pressure front higher than atmospheric pressure. The peak magnitude of the wave experienced by a patient becomes lessened the farther the person is from the centre of the explosion. The increase in pressure from a blast can be so abrupt that high-explosive blast waves are also referred to as "shock waves." Shock waves possess a characteristic, brisance, that describes the shattering effect of the wave and its ability to cause disruption of tissues as well as structures. Tissue damage is dependent on the magnitude of the pressure spike and the duration of force application. The negative wave pulse refers to the phase in which pressure is less than atmospheric; it may last 10 times as long as the positive wave pulse. It occurs as air displaced by the positive wave pulse returns to fill the space of the explosion. It can lead to massive movements of air resulting in high-velocity winds.

The speed, duration, and pressure of the shock wave are affected by the following:

- The *size* of the explosive charge. The larger the explosion, the faster the shock waves and the longer they will last.
- The nature of the *surrounding medium*. Pressure waves travel much more rapidly in water, for example, and are effective at greater distances in water than in air.
- The *distance* from the explosion. The farther one is from the explosion, the slower the shock wave velocity and the longer its duration.
- The presence or absence of *reflecting surfaces*. If the pressure wave is reflected off a solid object, its pressure may be multiplied several times. For example, a shock wave that might cause minimal injury in the open can cause devastating trauma if the patient is standing beside a wall or similar solid object.

The changes in pressure produced by the shock wave are accompanied by transient *winds*, sometimes of very high velocity, that can accelerate small objects to speeds of greater than 100 metres per second (m/sec). A missile travelling at 15 m/sec can easily penetrate human skin; at 120 m/sec, a missile can enter any of the major body cavities and cause serious internal injury. Blast winds can also send the human body flying against larger, more stationary objects, or as mentioned previously, amputate limbs.

In an *underwater explosion*, a shock wave travels at greater velocity than in open air, thereby making it possible to receive injuries at three times the distance that would normally be required to receive such injuries. This is because positive pressures are higher and there are no negative pressures or high-velocity wind. Blast fragments and gases move shorter distances in water.

An explosion is significantly more damaging in *closed spaces* because of a limited dissipation environment for the forces involved and for the generation of toxic gases and smoke. The blast wave is magnified when it comes into contact with a solid surface such as a wall, causing patients near a wall to be hit with significantly higher pressure, resulting in increased risk of injury and death.

Remember the discussion of the types of tissue and the effect of trauma on tissues that contain air, water, or bone? Blast pressures cause destruction at the interface between tissues of different densities or the interface between tissues and trapped air. When the shock wave passes from a higher to lower density medium, a severe pressure disturbance develops at the interface of the denser medium. The result is fragmentation of the heavier medium, or spalling. When the shock wave contacts small gas bubbles, the bubbles are compressed and high local pressures are created, called implosion. The bubbles can then reexpand and cause further damage. *Acceleration and deceleration* of organs at their fixation points will occur in a manner similar to that in blunt trauma.

Tissues at Risk

Air-containing organs such as the middle ear, lung, and gastrointestinal tract are most susceptible to pressure changes. Junction between tissues of different densities and exposed tissues such as head and neck are prone to injury as well. The ear is the organ system most sensitive to blast injuries. The tympanic membrane evolved to detect minor changes in pressure and will rupture at pressures of 0.35 kg/cm^2 above atmospheric pressure. Thus, the tympanic membranes are a sensitive indicator of the possible presence of other blast injuries. The patient may complain of ringing in the ears, pain in the ears, or some loss of hearing, and blood may be visible in the ear canal. Dislocation of structural components of the ear, such as the ossicles conforming the inner ear, may occur. Permanent hearing loss is possible.

Notes from Nancy

When there is evidence of ear problems after an explosion, look for serious injury to the lungs.

Primary pulmonary blast injuries occur as contusions and hemorrhages. When the explosion occurs in an open space, the side toward the explosion is usually injured, but the injury can be bilateral when the victim is located in a confined space. The patient may complain of tightness or pain in the chest and may cough up blood and have tachypnea or other signs of respiratory distress. Subcutaneous emphysema (crackling due to the presence of air under the skin) over the chest can be palpated, indicating air in the thorax. Pneumothorax is common and may require emergency decompression (which will be covered in the chapter on pulmonary injuries) in the prehospital environment for your patient to survive. Pulmonary edema may ensue rapidly. If there is *any* reason to suspect lung injury in a blast victim (even just the presence of a ruptured eardrum), administer oxygen. Avoid giving oxygen under positive pressure, however (that is, by demand valve) because that may simply increase the damage to the lung. Be cautious as well with intravenous fluids, which may be poorly tolerated in patients with this lung injury and result in pulmonary edema.

One of the most concerning pulmonary blast injuries is arterial air embolism, which occurs on alveolar disruption with subsequent air embolization into the pulmonary vasculature. Even small air bubbles can enter a coronary artery and cause myocardial injury. Air embolism to the cerebrovascular system can produce disturbances in vision, changes in behaviour, changes in state of consciousness, and a variety of other neurologic signs.

Notes from Nancy

If the victim of a blast injury has any neurologic abnormalities, notify medical control at once!

Solid organs are relatively protected from shock wave injury but may be injured by secondary missiles. Hollow organs, however, may be injured by similar mechanisms as for lung tissue. Perforation or rupture of the bowel and colon is a risk. Underwater explosions result in the most severe abdominal injuries.

Neurologic injuries and *head trauma* are the most common causes of death from blast injuries. Subarachnoid (beneath the arachnoid layer covering the brain) and subdural (beneath the outermost covering of the brain) hematomas are often seen. Permanent or transient neurologic deficits may be secondary to concussion, intracerebral bleeding, or air embolism. Instant but transient unconsciousness, with or without retrograde amnesia, may be initiated not only by head trauma, but also by cardiovascular problems. Bradycardia and hypotension are common after an intense pressure wave from an explosion. This is a vagal nerve–mediated form of cardiogenic shock without compensatory vasoconstriction (for example, vasovagal syncope).

Extremity injuries, including traumatic amputations, are common. Other injuries are often associated with tertiary blasts. Patients with traumatic amputation by postblast wind are likely to sustain fatal injuries secondary to the blast. In present combat, improved body armour has increased the number of survivors of blast injuries from shrapnel wounds to the torso. The number of severe orthopaedic and extremity injuries, however, has increased. In addition, while body armour may limit or prevent shrapnel from entering the body, it also "catches" more energy from the blast wave, possibly resulting in the victim being thrown backward, thus increasing potential spine and spinal cord injury.

Although blast injuries have usually been the domain of military surgeons, they often occur in industrial settings and are, unfortunately, more common today owing to the increased use of explosives as a tool for urban terrorism. Although civilian blast injuries in an industrial or mining setting used to be mostly characterized by blast injuries and burns, terrorist bombs often have shrapnel. Paramedics should be fully educated and aware of what to expect in these scenarios.

You are the Paramedic Summary

1. What initial information about the fall gives rise for concern?

The height of buildings without occupants and drug-related nature of the incident create concern about safety issues for yourself, your partner, the police, and the general public at large.

2. How does knowing your primary service area impact your understanding of potential patient injuries?

Being familiar with various aspects of your response area can aid you in understanding potential hazards or general conditions of an area. In this case, because it is a nonresidential area with buildings much higher than a typical single-family residence, you begin to wonder about the height of the fall and extent of the patient's injuries.

3. Given the location, what other conditions are you worried about?

This is a business location where the ground will be asphalt or concrete. The surface that an individual lands on implies much information about the forces placed on the body. Residential areas have more areas with grass, dirt, or gravel, which can absorb energy as a result of the impact of a fall.

4. Given commonalities of fire escape locations, what other information do you have?

If the fire escape is located in an alley, the patient can become entangled in lines or wires of various uses and can land on objects such as parked cars, dumpsters, or other people.

5. How does your patient's condition hinder your assessment techniques?

Patients under the influence of drugs can be unwilling or unable to provide reliable information about their injuries because their mentation and ability to perceive pain can be greatly diminished. When a patient not under the influence would guard an injury or self-splint a fracture, patients under the influence have lost these safety mechanisms and can fail to provide feedback that could aid you in determining the extent of their injuries.

6. How do you compensate for this hindrance?

You must rely on the information given to you by the mechanism of injury, any available witnesses, and your assessment techniques to determine the location and nature of the patient's injuries. Understanding the forces placed on the body in common traumatic injuries will aid you in treating obvious and not obvious injuries.

7. Given this information, what other injuries do you suspect?

Given the height of the fall and his position upon landing, you would also suspect lumbar spine fractures. The force of landing on pavement will travel up the heels, legs, and into pelvis and spine.

8. How can a patient who is under the influence of drugs be difficult to manage?

These patients will fail to comply with simple commands or treatment, and you may find it extremely difficult to provide necessary treatment. Depending on their reaction to the drugs, they can remove intravenous lines and otherwise fail to remain still despite obvious injuries.

9. What other medical emergencies can ensue from the use of PCP?

Depending on the amount and route of administration, PCP can result in hallucinations, paranoia, psychosis, cardiac arrhythmias, seizures, hyperthermia, kidney failure, and death. Sedation may be required, especially if the patient cannot be restrained by other means. Any patient who requires restraints must be continually monitored, particularly if chemical restraints must be used.

10. What will remain a concern throughout this call?

When dealing with a patient who is under the influence of drugs or alcohol and who exhibits combative behaviour, you must remain diligent regarding scene safety. These patients can be very unpredictable, and law enforcement personnel should accompany you in the ambulance during transport.

Prep Kit

Ready for Review

- Trauma is the primary cause of death and disability in people 1 to 45 years old.
- The amount of force and energy delivered are factors in the extent of trauma sustained. Duration and direction of the force of application are also important.
- Understanding the effects of forces and energy will help in developing a high index of suspicion for the mechanism of injury and the likely types of injuries.
- There are three categories of trauma centres accredited by the Trauma Association of Canada. Tertiary care trauma centres provide the highest level of care and are the equivalent of Level I centres as described by the American College of Surgeons. Your local EMS system may have other designations for trauma referral centres.
- Situations in which there is extended transport time by ground, mass casualties, prolonged extrication times, and critically injured patients, or when there is a long distance to an appropriate facility may warrant transporting a patient via air medical transport.
- Kinetic energy (KE) of an object is the energy associated with that object in motion. It reflects the relationship between the weight (mass) of the object and the velocity at which it is travelling.
- In a motor vehicle collision, the angle of impact, mechanical characteristics of the vehicle, and the occupant's position at the time of impact will determine types of injury.
- The law of conservation of energy states that energy can be neither created nor destroyed, it can only change form.
- Trauma in a collision is composed of five phases representing the effects of progressive deceleration: deceleration of the vehicle, deceleration of the occupant, deceleration of internal organs, secondary collisions, and additional impacts.
- There are five primary types of impacts: frontal or head on, lateral or side, rear, rotational, and rollover.
- The front seat occupants of vehicles during a frontal or head-on collision usually follow one of two trajectories, a down-and-under pathway or an up-and-over pathway.
- Protective devices such as seatbelts, air bags, and helmets are designed to manipulate the way in which energy is dissipated.
- Adult pedestrians involved in a collision experience three predominant mechanisms of injury: lower extremity injuries from the initial hit, second impact injuries from being thrown onto the hood or grille, and third impact injuries when the body strikes the ground or another object.
- The severity of injuries from falls from heights depends on the height, position, and orientation of the body at the moment of impact; the area over which the impact is distributed; the surface onto which the person falls; and the physical condition of the patient.
- The severity of a stab wound depends on the anatomical area involved, depth of penetration, blade length, and angle of penetration. Carefully document the location of stab wounds.
- Firearms are the primary mechanism resulting in penetrating trauma. The magnitude of tissue damage depends on the projectile's velocity, the orientation of the projectile as it entered the body, the distance from which the weapon was fired, the design of the projectile, and the type of tissue through which the projectile passed.
- Blast injuries include primary, secondary, tertiary, and miscellaneous injuries.

Vital Vocabulary

acceleration The rate of change in velocity.

acute respiratory distress syndrome (ARDS) A respiratory syndrome characterized by respiratory insufficiency and hypoxemia.

angle of impact The angle at which an object hits another; this characterizes the force vectors involved and has a bearing on patterns of energy dissipation.

arterial air embolism Air bubbles in the arterial blood vessels.

avulsing A tearing away or forcible separation.

barometric energy The energy that results from sudden changes in pressure as may occur in a diving accident or sudden decompression in an airplane.

biomechanics The study of the physiology and mechanics of a living organism using the tools of mechanical engineering.

blast front The leading edge of the shock wave.

blunt cardiac injury Contusion as the heart is compressed between the sternum and the spine.

blunt trauma An impact on the body by objects that cause injury without penetrating soft tissues or internal organs and cavities.

brisance The shattering effect of a shock wave and its ability to cause disruption of tissues and structures.

cavitation Cavity formation; shock waves that push tissues in front of and lateral to the projectile and may not necessarily increase the wound size or cause permanent injury but can result in cavitation.

chemical energy The energy released as a result of a chemical reaction.

deceleration A negative acceleration, that is, slowing down.

electrical energy The energy delivered in the form of high voltage.

entry wound The point at which a penetrating object enters the body.

exit wound The point at which a penetrating object leaves the body, which may or may not be in a straight line from the entry wound.

gravity The acceleration of a body by the attraction of the earth's gravitational force, normally 9.8 m/sec^2.

implosion A bursting inward.

kinetic energy The energy associated with bodies in motion, expressed mathematically as half the mass times the square of the velocity.

kinetics The study of the relationship among speed, mass, vector direction, and physical injury.

law of conservation of energy The principle that energy can be neither created nor destroyed, it can only change form.

mechanical energy The energy that results from motion (kinetic energy) or that is stored in an object (potential energy).

missile fragmentation A primary mechanism of tissue disruption from certain rifles in which pieces of the projectile break apart, allowing the pieces to create their own separate paths through tissues.

negative wave pulse The phase of an explosion in which pressure from the blast is less than atmospheric pressure.

Newton's first law of motion The principle that a body at rest will remain at rest unless acted on by an outside force.

Newton's second law of motion The principle that the force that an object can exert is the product of its mass times its acceleration.

pathway expansion The tissue displacement that occurs as a result of low-displacement shock waves that travel at the speed of sound in tissue.

penetrating trauma Injury caused by objects that pierce the surface of the body, such as knives and bullets, and damage internal tissues and organs.

permanent cavity The path of crushed tissue produced by a missile traversing part of the body.

positive wave pulse The phase of the explosion in which there is a pressure front with a pressure higher than atmospheric pressure.

potential energy The amount of energy stored in an object, the product of mass, gravity, and height, that is converted into kinetic energy and results in injury, such as from a fall.

pulmonary blast injuries Pulmonary trauma resulting from short-range exposure to the detonation of high explosives.

shearing An applied force or pressure exerted against the surface and layers of the skin as tissues slide in opposite but parallel planes.

spalling Delaminating or breaking off into chips and pieces.

trauma Acute physiologic and structural change that occurs in a victim as a result of the rapid dissipation of energy delivered by an external force.

tympanic membrane The eardrum; a thin, semitransparent membrane in the middle ear that transmits sound vibrations to the internal ear by means of the auditory ossicles.

velocity The speed of an object in a given direction.

Waddell triad A pattern of vehicle–pedestrian injuries in children and people of short stature in which (1) the bumper hits pelvis and femur, (2) the chest and abdomen hit the grille or low hood, and (3) the head strikes the ground.

whiplash An injury to the cervical vertebrae or their supporting ligaments and muscles, usually resulting from sudden acceleration or deceleration.

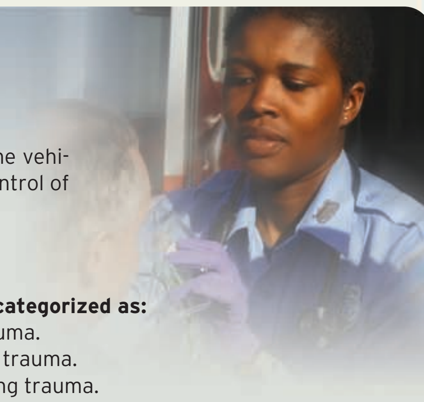
Points to Ponder

You and your partner are dispatched as a second paramedic unit to assist in a two-car motor vehicle collision. You arrive on scene and are directed to a vehicle approximately 100 metres from the initial impact. Witnesses state that this vehicle was struck on the passenger side at a high rate of speed and slid out of control through a metal fence and the driver's side is now resting against a large tree. You are told that the other vehicle involved in the collision drove through a red light, driving approximately 80 km/h. The passenger side has an intrusion of more than 60 cm. There are two women inside the van. They are conscious, alert, and orientated and very upset, crying hysterically. The fire department is extricating the patients from the vehicle.

What is the mechanism(s) of injury to the vehicle? What type of injuries would you suspect the patients may have? What are major concerns and thoughts you must have during your assessment and treatment of these trauma patients? What level trauma hospital would you take these patients to?

Issues: Understanding Kinematics of Trauma, Predicting Injury Patterns, Examining the Scene and Patients, Knowledge of Trauma Centre Levels.

Assessment in Action



You are dispatched for a single motor vehicle collision and encounter a wet, slippery road. The driver of the vehicle is slumped in the driver compartment. Witnesses tell you that she was driving and then suddenly lost control of her vehicle, struck a mail box, and then drove head on into a telephone pole.

1. **What is Newton's first law of motion?**
   - **A.** The force that an object can exert is the product of its mass times its acceleration.
   - **B.** A body at rest will remain at rest and a body in motion will remain in motion unless acted on by an outside force.
   - **C.** Energy cannot be created or destroyed but can be changed in form.
   - **D.** Kinetic energy is a function of an object's weight and speed.
2. **Trauma in a collision is composed of how many phases, which represent the effects of progressive deceleration?**
   - **A.** 2
   - **B.** 3
   - **C.** 4
   - **D.** 5
3. **A patient's ability to dissipate the energy determines the pattern of injury.**
   - **A.** True
   - **B.** False
4. **What type of impact would you suspect in the preceding scenario?**
   - **A.** Lateral
   - **B.** Rear
   - **C.** Frontal
   - **D.** Rotational
5. **Injuries are generally categorized as:**
   - **A.** head and spinal trauma.
   - **B.** extremity and body trauma.
   - **C.** blunt and penetrating trauma.
   - **D.** closed and open trauma.
6. **The role of air bags is to:**
   - **A.** cushion forward movement of the occupant.
   - **B.** protect the occupant from ejection.
   - **C.** accelerate the occupant away from the point of impact.
   - **D.** block the occupant's view of the impact.

Challenging Questions

You are dispatched to a woman who has fallen. On arrival, you find a 38-year-old woman supine on the ground. Initially, she is responsive to deep painful stimuli.

7. **The severity of injuries will depend on a number of factors that will be important in assessing the patient. List these factors.**