Chapter 1
MECHANISMS OF INJURY

INTRODUCTION

Trauma starts with the transfer of energy to the body from an outside force. The transfer of kinetic energy may be blunt or sharp in nature. In addition to blunt and sharp mechanisms, there is the situation of thermal energy in the form of heat, cold, or chemical agent, which generates the heat or cold. With the event of more frequent war-like situations, blast injuries and other mass casualty events are more common from improvised explosive devices (IED) or other mass disasters and are discussed in Chapter 15. Because the mechanism drives the injury sustained, injury prevention goes hand in hand. Table 1-1 identifies common mechanisms and the appropriate e-code for each (ICD9-CM 2008).

Trauma remains the leading cause of death in individuals aged 1 to 44 years, with the majority of injuries preventable (www.cdc.gov/ncipc/osp/data.htm). Motor vehicle collisions are the leading cause of trauma death in all age groups between 1 to 65 years. In individuals over 65 years, falls become the leading cause of death. The most common causes of nonfatal injuries as reported by the Centers for Disease Control and Prevention (CDC) are the following:

- Falls: 0 to 14 years and 25 years and older
- Unintentionally struck: leading cause of injury 15 to 24 years
- Motor vehicle collisions: second leading cause of injury 15 to 24 years.

Table 1-1 E-codes for Common Mechanisms of Injury (ICD9-CM 2008)

MOI	E-code (ICD9-CM)	Comments
MVC x represents the fourth digit, meaning occupant position		
MV to MV	E812.x	Any two motorized vehicles involved in the collision, even if one is stationary or parked
MV to object in road	E815.x	Any motorized vehicle impact with an on-the-road object, such as an animal, road sign, median, overpass; not an off-road stationary object, such as a tree
MV to object off road	E816.x	See loss of control
MV loss of control	E816.x	Any loss of control on the road including leaving the road and ultimately crashing into an off-road object; rollover
Car surfing	E818.1	Standing on vehicle while moving
MVs to MV off-road	E821.x	MVC in vehicle traveling wholly off streets/roads, ATV
Off-road snow vehicle	E820.x	Snowmobiles
Pedestrian struck	E814.7	Pedestrian struck by any motorized vehicle on the road
Bicycle struck	E813.6	Any pedal cycle struck by any motorized vehicle on the road
Falls		
GLF	E888.8	General GLF without other specifics
GLF struck sharp object	E888.0	GLF in which a sharp object is struck en route to ground

(*Continued*)

Table 1-1 E-codes for Common Mechanisms of Injury (ICD9-CM 2008) (*Continued*)

MOI	E-code (ICD9-CM)	Comments
Falls		
GLF struck blunt object	E888.1	GLF in which a blunt object is struck en route to ground
Slip, trip fall	E885.9	GLF from slipping, tripping and then falling
Fall from bike	E826.1	Riding bike, then collision on own, fall off
Fall OOB	E884.4	Fall from bed
Fall from chair	E884.2	Fall from chair
Fall while skiing	E885.3	Fall while skiing
Fall from snowboard	E885.4	Fall while snowboarding
Fall from skateboard	E885.2	Fall off roller skates, ice skates, in-line skates
Trip over curb	E880.1	Fall from tripping over a curb
Fall from toilet	E884.6	Fall from toilet
Fall from ladder	E881.0	Fall from ladder any height
Fall from building	E882	Fall from roof, other building, balcony
Fall in sports	E886.0	Collision or other cause of a fall during sports activities
Fall into hole	E883.9	Fall into a hole
Fall down steps	E880.9	Fall down any number of stairs
Fall from other	E884.9	Fall from height other object not found in the list
Struck—unintentional		
Without fall	E917.x	Struck unintentionally by object or persons without a fall

(*Continued*)

Table 1-1 E-codes for Common Mechanisms of Injury (ICD9-CM 2008) (*Continued*)

MOI	E-code (ICD9-CM)	Comments
Struck—unintentional		
In sports, no fall	E917.0	Struck unintentionally in sports activities without subsequent fall
Crushed between objects	E918	Caught between two objects, crushed
By falling object	E916.0	Struck by any falling object
Others		
Lawnmower	E920.0	Injury while using a lawnmower, powered or not
Cut by glass	E920.8	Unintentional cut by glass
Unintentional GSW	E922.x	Gunshot, unintentional
Unintentional stab	E920.3	Injury caused by sharp implement, unintentional
Homicide		
Assault	E960.0	Struck by fists, kicked, assaulted
Assault with object	E968.2	Struck by object during assault, pistol-whipped, baseball bat, concrete block, etc
Assault with vehicle	E968.5	Intentionally struck by vehicle
Rape	E960.1	Rape
GSW	E965.x	Intentional gunshot; fourth digit represents weapon
Stab	E966	Intentional stab with implement
Abuse	E967.x	Abuse of child, adult, elderly; inflicted by another
Set on fire	E968.0	Intentional burning by fire

(*Continued*)

Table 1-1 E-codes for Common Mechanisms of Injury (ICD9-CM 2008) (*Continued*)

MOI	E-code (ICD9-CM)	Comments
Suicide		
Hanging	E953.0	Intentional self-inflicted hanging, suffocation, asphyxiation, not caused by chemicals
GSW	E955.x	Intentional self-inflicted gunshot
Stabbing/cutting	E956	Intentional self-inflicted stab/cutting
Vehicle	E958.5	Intentional injury to self with a vehicle
Burn		
Conflagration	E890.x	Housefire or fire in a building
Conflagration—bed	E898.0	Housefire started in bed occupied by the injured
Jump burning building	E890.8	Jumping from a burning building
Hot water scald	E924.2	Burn from hot water—tap Burn from hot water—heated
Hot substance/liquid scald	E924.0	Burn from other hot substance
Hot object	E924.8	Burn from touching hot object
Frostbite	E901.x	Burn from cold exposure, causing frostbite
Chemical	E924.1	Burn from chemical—acid Burn from chemical—alkali
Electrical	E925.x	Burn from electrical source

(*Continued*)

Table 1-1 E-codes for Common Mechanisms of Injury (ICD9-CM 2008) (*Continued*)

MOI	E-code (ICD9-CM)	Comments
Bites/Animal		
Dog	E906.0	Bite from dog
Kicked by animal	E906.8	Other injury inflicted by animals, such as gored, kicked, fallen upon
Fall off horse	E828.2	Fall off horse being ridden
Venomous snake	E905.0	Bite from venomous snake
Human	E968.7	Bite from human, intentionally inflicted
	E928.3	Bite from human, unintentional

The word "accident" will not be used in this text because of the preventable nature of trauma and the need for professionals to address trauma as a preventable disease, not happenstance, acts of god, and so on (Sisley 2007). Injury prevention activities by healthcare staff are hindered by time, education, and resources (Wilding et al. 2008), although hospital providers have the prime opportunity for these efforts. Every patient presents an injury prevention teaching opportunity. Natural disasters are some of the few "accidental" situations. Trauma is referred to as intentional versus unintentional in order to address the more appropriate nature of the event. For example, drunk driving is preventable, yet the injuries are usually unintentional. C. Everett Koop, former U.S. Surgeon General, made a profound statement regarding trauma: "If a disease were killing our children in the proportions that injuries are, people would be outraged and demand that this killer be stopped."

BLUNT TRAUMA

Blunt trauma occurs when the force applied to the body is not sharp in nature. Forensic medicine refers to blunt versus sharp injuries. Thus gunshot wounds (GSW) are classified as blunt to the medical examiner because the bullet is not a sharp implement. However in the trauma center, trauma is divided into blunt and penetrating, and placing GSW in the penetrating category because of its action on the body.

Principles of physics that operate when trauma, both blunt and penetrating, occurs are

- A body in motion remains in motion until acted upon by an outside force
- Velocity of the load applied determines damage (force = mass × acceleration)
- Tissue is displaced in the direction of the moving object (especially important for forensic evaluation)
- If an object is deformable, the time to impact is increased and thus the damage is increased
- Kinetic energy transferred is additive (both objects moving); $^1/_2$ mass × velocity^2.

Blunt trauma results in fracture, laceration, and other external wounds, tearing by shear forces, pressure causing "blowout" type injuries, and coup–contrecoup (side to side) injuries that are bilateral caused by the recoil after initial impact. This chapter will discuss common mechanisms and the expected injuries that result.

Motor Vehicle Collisions

Motor vehicle collisions (MVC) are usually unintentional; however some individuals have attempted suicide or homicide through the use of a vehicle. Most collisions begin on a street or highway and end with the collision itself. MVC can also occur in off-road situations, such as snowmobiles, all-terrain vehicles (ATV), and motocross or motorbikes. In addition, the

position of the occupant at the time of impact determines injury. Since most collisions are unexpected, it is not uncommon for the occupant to inhale and hold the breath at the moment of impact. The blow to the chest that follows compresses the air-filled lungs resulting in pneumothorax. Car surfing and riding in the back of a pickup truck provide no protection for the occupant and result in the potential for total body injury.

Depending upon the choice of restraint, the individual has several options while in the vehicle. The unrestrained occupant has a greater chance of ejection from the seat through the "up and over" mechanism or entrapment under the dashboard via the "down and under" path. Restraints worn properly (lap and shoulder) hold the occupant in place with minimal movement as well as minimal injury. The airbag has room to deploy (at approximately 200 mph) without severe injury to the occupant. However, lap-only belts (that includes the shoulder belt placed behind the shoulder) result in the upper body coming in contact with objects in front of them (steering wheel, airbag) and shoulder-only results in the pelvis sliding downward and the neck becoming entrapped by the shoulder belt. Table 1-2 describes injuries associated with these pathways. The table includes the injuries to children improperly restrained. Restraint requirements for pregnant women and children are discussed below in injury prevention. Occupants in reclined seats have demonstrated severe torso injury while wearing the seat belt, lower extremity injury, and an increased mortality (Dissanaike et al. 2008). Serious injuries sustained while properly restrained would likely have resulted in death if unrestrained.

Head-on or rear-end collision

Most commonly involves the up and over or down and under pathways unless restrained. An impact with the steering wheel at 30 mph is comparable to standing against a wall and having a telephone pole rammed into the chest. Organs with ligamentous attachments (eg, aorta, liver, spleen) are particularly susceptible to injury. In the down and under path, the femur

Table 1-2 MVC-related Mechanisms of Injury

Pathway	Potential Injuries
Unrestrained—"up and over"	Head, face, and neck injuries from impact with windshield or sunroof Chest injuries—steering wheel impact Abdominal injuries—steering wheel impact (dependent upon body habitus) Airbag injury to face, neck, chest Lower extremity injury if tangled under dash/gas-brake pedals
Unrestrained—"down and under"	Lower extremity injuries—crush mechanism; entrapped in pedals, knee fracture/dislocation, hip fracture/dislocation Pelvis injury impact Abdominal injury—crush, impalement, body habitus affects Possible chest injury, neck injury
Lap-only belt	Head, neck, face injury from steering wheel impact, especially larynx/trachea; airbag injury Chest injury—steering wheel impact Potential for ejection or partial ejection and windshield impact
Shoulder-only belt	Neck vascular injury, head injury Abdominal injury—steering wheel impact
Improperly worn restraints	Lap belt too high: abdominal hollow viscus injury, thoracic and lumbar spine injury Lap belt too loose: hyperflexion injury at T12- L1 vertebrae Lap belt too high in pregnant passenger: abdominal injury as above in addition to injury to the fetus, placenta, uterus (determined by the age of the fetus)
Car seat not tethered to vehicle	Ejection; becomes a missile to other passengers All injuries, especially atlantooccipital dislocation with spinal cord injury from large head and inevitability of landing face down

(*Continued*)

Table 1-2 MVC-related Mechanisms of Injury (*Continued*)

Pathway	Potential Injuries
Child <12 years, front seat	Airbag impact to chest, abdomen, head, face Broad cadre of injury if unrestrained
Rear-facing car seat, front seat	Airbag impact to the car seat results in severe head, neck injury
Child <4′8″ or 60 lb in adult restraint	Slides under the seat belt as above "down and under," or If lap only, folds in half resulting in hollow viscus abdominal injury and chance fracture with spinal cord injury at L1-L2 vertebrae
Airbag Injuries	Airbags require a collision >35 mph to deploy and unless lateral airbags present, no deployment in lateral collisions Injuries to upper extremities, face, neck, corneal abrasions, chest Burns or abrasions may occur Seated too close (<10-14 in) can result in cervical hyperflexion injury Airbag only—54% increase in cervical spine injury in drivers (Donaldson et al. 2008)

strikes the dashboard ramming the bone into and through the acetabulum and causes pelvic fracture as well as posterior dislocation. Particularly in rear-end collisions, the position of the headrest can result in either injury to the neck or protection of the neck. Cervical ligamentous injury can result after hyperextension of the neck over the headrest. The headrest should be positioned properly at the midposterior skull.

Lateral impact (T-bone)

Injury occurs in a lateral impact determined by the degree of intrusion and any car components striking the occupant. For example, the control panel on the driver's door will impact the

hip if it protrudes into the passenger compartment and the body habitus of the driver in relation to its position. Common injuries in lateral impact are determined by the position in the vehicle as well as restrained and reclined seats. The driver should be observed for aortic injury, spleen, rib fractures, pelvis fracture, left upper extremity injury. For the front passenger struck on the passenger side, anticipate liver, rib, pelvis, and right upper extremity injury. Unrestrained occupants will be pushed toward the opposite side, either into the door or other passengers and have a significant increase in mortality (Ryb et al. 2007).

Motorcycle and bicycle crashes

Head-on collision frequently results in the rider ejecting or partially ejecting over the handlebars. Common injuries include

- Head and neck injury if no helmet in place
- Thoracoabdominal injury from handlebar impact (common in children)
- "Open book" pelvic fracture—a splaying open (like a book) of the anterior and posterior pelvis from striking the handlebars
- Bilateral femur fracture
- Skin abrasions, lacerations

Injuries are decreased when a helmet is in place in proper position and if protective clothing is worn. Angular collisions or collisions with a vehicle result in multiple overall injuries and are dependent upon the site of impact. There is no demonstrated relationship between cervical spine injury and the use of a helmet (Goslar et al. 2008). Helmets are known to be protective of the head.

Pedestrian struck by vehicle

Pedestrian injuries are injuries sustained when an individual is struck by a vehicle but is not traveling in or on a motorized conveyance. For example, the wheelchair, skateboard, in-line skates, walking individual struck by a vehicle are pedestrian situations. Small children struck by vehicles are usually knocked

over by the bumper and then run over by the tires. This is not due to driver intention, but rather the child's low center of gravity that causes him or her to fall over. The child not seen is now under the tire and run over before the driver can realize that the car has struck something.

School-age children and short adults are struck by the bumper in the femur/distal femur. When the pedestrian is taller, the impact is lower on the leg, most commonly the tibia. If the individual is facing toward or away from impact, bilateral tibia will be involved. If the individual is struck while walking, one side will take the impact. The victim is then either thrown away from the vehicle causing extremity, pelvis, thoracoabdominal, head/neck injuries, or flips up onto the hood of the vehicle and strikes the windshield increasing the potential for head, neck, and face injury.

A larger vehicle, such as a truck or SUV that has a higher bumper will strike the pedestrian at a higher site, such as the pelvis or abdomen, or perhaps the chest in a child. If the driver realizes an impact may occur and applies the brakes, the pedestrian will be struck lower on the body as the braking drops the bumper slightly lower.

Other Transport

The human body can be transported by multiple means. Other than MVC, the most common conveyances resulting in injury are bicycles and animals being ridden, such as horses and bull-riding. There are other conveyances, such as skateboards, skis/snowboards, and in-line skates, which have a fall event or if struck by a car, are similar to a pedestrian injury. Boating injuries occur and the clinician must consider the mechanism and identify if immersion or submersion was involved as well as exposure to other environmental issues, such as cold. Airplane/helicopter crashes are usually severe because of the velocities achieved during the fall or the severity of the crash (in air or on the ground). Vehicle-type injuries occur with or without burns if the passenger survives the event. This includes, of course, ultralight and other such craft falling from flight.

Bicycle and ATV

Because these vehicles transport a rider in the same unprotected way as a motorcycle, the mechanisms causing injury are the same as for motorcycles. Speed and place of injury may determine different circumstances of injury. Attention to the details of the event will provide the clues to suspected injuries.

Animal being ridden

A rider thrown from an animal being ridden is similar to a pedestrian struck by a vehicle. The impact is increased by the height of the fall and the degree to which the animal throws the rider.

Falls

Falls remain one of the most common mechanisms across the age groups, with the highest occurrence in children and the elderly. Falls can be as simple as tripping or slipping on a wet surface to falls from significant height, like parachutes and bungee jumping, that result in severe injuries. Diving injuries may not be caused by a high fall; however they involve the striking of the head/neck on the bottom surface resulting in hyperflexion. Other falls include falling downstairs, off playground equipment, or simply off a curb, or more serious intentional injuries, like jumping from a balcony or bridge. The mechanics of the fall and the position of landing give clues to the injuries sustained. In the case of intentional injury, psychiatric support must be anticipated in addition to identifying and managing the injuries.

Ground level

Simple ground level falls (GLF) happen to all age groups, however injury occurs more often in the elderly as the bones are more fragile. It is not uncommon for a ground level fall with a hip fracture to progress to a serious decrease in function and possibly death. Lumbar vertebra injuries are common as well as cervical spine injury from hyperflexion of the neck. Most GLF result in fractures or head injury dependent upon the surface and if a sharp or blunt object is struck on the way to the ground. In the elderly, a subdural hematoma is not uncommon,

but normally progresses slowly. The patient and family may not remember the fall by the time symptoms occur from a slow hemorrhage.

Axial load

Falls from a height result in an axial load. It is important to identify the body part on which the victim landed. For example, landing on the feet can result in calcaneus and long bones fractures and possibly lumbar or thoracic spine fractures as the force travels up the body. Sometimes the victim has struck something on the way down resulting in injury to other body parts. The thoracic aorta due to its ligamentous attachments is particularly susceptible. Solid organs also do not tolerate the stress of the axial load and will fracture. The force of impact must be understood, for example, a fall of 10 ft is like catching a 200 lb bag of cement thrown out of a first story window.

Other

Other blunt trauma mechanisms include windsurfing, machinery crush mechanisms, falling objects, or sports injuries. Injuries are dependent upon the site of impact, transfer of energy, and environment.

PENETRATING TRAUMA

Penetrating injuries result from an object entering the body and sometimes exiting the body causing damage along the path. The object may not penetrate the fascia resulting in an external injury only. More commonly the object penetrates the fascia and injures underlying structures resulting in "open" injuries. On occasion the implement may still be present in the body. The velocity, size of the implement, and direction of entry and path determine the injuries.

Gunshot Wounds

Gunshot wounds (GSW) are usually intentional (suicide, homicide) but can be unintentional (hunting, gun not in holster, gun

cleaning). Handguns are usually low-velocity weapons whereas rifles are high-velocity that inflict greater damage. However, not all handguns are low-velocity. The bullet forms a cavity that is a permanent hole and due to compression during entry, the surrounding tissue is pushed out of the way and deformed resulting in surrounding damage. There is also a shock wave present ahead of the bullet, which has a concussive effect. This wave causes serious injury in air- and fluid-filled spaces, like the lung. Other mechanisms at work with gunshots include

- Yaw: vertical and horizontal oscillation about the axis of the bullet; can result in a larger surface area on impact with the body depending on the position of the bullet on the axis at time of impact.
- Tumbling: rotation of the bullet upon impact resulting in some parts of the cavity larger than others as the bullet rotates along the path.
- Rifling: spiraling grooves within the barrel of the weapon put spin on the bullet as it exits the barrel; provides stability in flight along the axis.
- Hollow-point bullets: deform on impact causing a larger surface area to inflict damage.
- Shotgun: multiple pellets within the cartridge; also possible to have one large projectile, such as a "pumpkin ball," both air resistance and gravity spread the pellets over distance; closer shotgun wounds result in serious large wounds as the pellets remain clumped together.

The bullet does not usually travel in a straight path. This results in the need for exploration as multiple injuries can occur although the path appears to be in a straight line. Intentional injuries may require either psychiatric support (suicide attempts) or safety (homicide attempts).

Stabbing

Stabbings are also usually intentional (suicide, homicide) but can be unintentional, (eg, a slip on wet floor and landing on open dishwasher with knives pointing upward). A stabbing most often

follows a direct path, is low velocity resulting mostly in damage along the line of the path itself, and are of varying depth. The type of blade affects the wound inflicted, such as straight blade versus a serrated edge. From a forensic medicine perspective, a stab is deeper than it is long and a cut is longer than deep. A cut differs from a blunt laceration in that the edges are clean and the direction of the wound inflicted indicates the direction of the force.

Stabs to the chest and abdomen are particularly important to investigate as the angle of the penetration may indicate that the wound crosses both cavities injuring the diaphragm in between the two.

Other

Impalement on objects (see Chapter 8, Figures 8-3 and 8-4) is another means of causing a penetrating injury. As with a typical stabbing by knife, the wound must be investigated and a determination made regarding both surgery and/or repair. Impalements have occurred on fences during rollover MVC, pieces of wood ejected from a saw, and various other and sometimes surprising mechanisms. The anticipated injuries are approached in the same manner as a knife stabbing.

Other "sharp" or penetrating injuries can occur from tools and machinery, fan blades, and other objects with a sharp edge. Any penetrating event results in "open" injuries in which the underlying injury has a direct communication with the external world via the wound path. Be aware that all penetrating events cause open injuries but not all open injuries are from penetrating mechanisms. An open fracture during an MVC is blunt trauma with an open fracture caused by the bone connecting with the environment from the inside-out.

BURNS

Thermal

Thermal burns are caused by extreme cold or long cold exposure with or without humidity or exposure to heat/direct flame. Exposure to heat can be in the form of hot air, hot water, chemicals

with an exothermic reaction, or other hot substance. For example, water temperature of 140°F (60°C) causes a deep partial thickness to full thickness burn in 3 seconds of exposure (Auerbach 2007). Conflagration is the most common form of burn injury and is preventable by early warning from a smoke detector, not smoking in bed, and proper positioning of heating devices. Over 40% of house fires involve drug and alcohol use. Up to 25% of residential fires involve smoking (ENA 2007). Details on burn events and care are found in Chapter 10.

Other

Chemical burns can result from direct injury of the chemical and the skin interaction or indirect injury when the chemical results in an exothermic reaction producing heat. Some antidotes for chemicals produce the exothermic reaction of the chemical causing more injury than the chemical exposure itself.

Radiation exposure can also result in burn with the depth of burn varying with the type of radiation and length of exposure. The types of injury resulting from radiation exposure are discussed in Chapter 15.

Lightning causes up to 100 deaths per year in the United States. However, overall mortality is low due to a more common "flashover" burn rather than a high-voltage electrical injury. The flashover burn resulting from a lightning exposure is very superficial. The electrical and sound impact is more serious resulting in arrest, tympanic membrane rupture, and cataracts. Retinal detachment occurs with telephone-mediated lightning strikes.

Electrical, particularly high voltage, exposure results in serious burns from the inside out. The voltage travels along the nerves burning and coagulating tissue along the path to the exit from the body.

SPECIAL SITUATIONS—RISKS

Women

Overall, trauma in women spans all possible mechanisms, both blunt and penetrating. The risk for injuries to the genitourinary

tract in women is actually low due to the safe positioning within the pelvis and the short length of the urethra. Pelvic fractures however, can result in vaginal lacerations with associated open, and now contaminated, pelvic fractures.

For women of childbearing age (10–50 years), 1 in every 12 pregnant women will sustain some injury with 4 in 1000 requiring medical admission for management (Hoyt and Selfridge-Thomas 2007, Mattox et al. 2000, ATLS 2008). A pregnant trauma patient also has a nearly 2 times increased risk of preterm delivery (Shah and Kilcline 2003).

In the pregnant woman, trauma is the leading cause of nonobstetrical maternal death (Ikossi et al. 2005, Shah et al. 1998, ENA 2007). The majority of these maternal deaths occur in the third trimester (Hoyt and Selfridge-Thomas 2007, ENA 2007). Head injury and shock are the leading causes of death for the mother although fetal survival is directly related to maternal shock (80%) and death (Hoyt and Selfridge-Thomas 2007, Patteson et al. 2007, Ziglar et al. 2004). Fetal death exceeds maternal death by a three-to-one ratio (Ikossi et al. 2005). The age of the fetus increases susceptibility to trauma especially after 24 weeks when the fetus is fully within the abdomen and is no longer protected by the pelvis. Gestational age at the time of delivery also affects fetal outcome (El-Kady et al. 2004, Shah and Kilcline 2003). Risk factors for fetal death include ejection from a vehicle, motorcycle crash, pedestrian struck by vehicle, and unrestrained in a MVC (Curet et al. 2000).

Blunt trauma is the most common mechanism of injury. In the pregnant trauma patient, the placenta is susceptible to the shear forces of blunt trauma caused by its inherent inelasticity resulting in abruptio placenta (Ziglar et al. 2004, ENA 2007, ATLS 2008). In pregnancy, MVC are the most common cause of injury (Ziglar et al. 2004, Patteson et al. 2007, Minow 1999, Metz and Abbott 2006, Mattox and Goetzi 2005, Baerga-Varela et al. 2000). Domestic violence during pregnancy occurs in at least 17% to 20% of women with up to 60% suffering repeated episodes of violence (Hoyt and Selfridge-Thomas 2007, Ziglar et al. 2004, ATLS 2008). These statistics are likely underestimated

and are poorly documented because women do not report the cause or do not seek medical attention. Domestic violence frequently increases as delivery approaches.

The pregnant woman is also susceptible to falls caused by changes in her center of gravity that result in an altered gait, laxity of the pelvic joints, and fatigue (Ziglar et al. 2004, ENA 2007). If burns occur to the pregnant trauma patient there is an increased morbidity of up to 65% with burns of 20% to 50% TBSA (Ziglar et al. 2004). Delivery is recommended if TBSA exceeds 50%. It is essential to monitor the pregnant burn patient for carbon monoxide (CO) poisoning. Fetal hemoglobin has a much higher affinity for CO, which impairs the release of oxygen to the fetus.

Pediatrics

Over 10 million visits to the emergency department by children are due to injury. More than 10,000 of these children die (ATLS 2008). Approximately 11% of all pediatric intensive care unit admissions are trauma patients (Ponsky et al. 2005). Trauma remains the leading cause of death for children over 1 year and the second leading cause of death for those under 1 year (CDC-NCIPC 2008; Ziglar et al. 2004). The leading mechanism of injury resulting in death is MVC. In children under 10 years, unintentional drowning and burns are the second leading cause of death. The second leading cause of death for children over 10 years is homicide by firearms and suicide events. Falls are the leading cause of emergency department visits and admissions (Stewart et al. 2004). The mechanism shifts to recreational injuries in children aged 10 to 14 years. As the mechanisms become MVC, there is an increase in injury severity score (ISS) as well.

One would expect mechanisms of injury in children to be primarily focused on play. However the leading causes of injury involve motor vehicles with children as passengers or pedestrians. The body of a child is not strong enough or made to fit the design of seat belts until 8 years and therefore requires a car seat or booster seat.

Falls are frequent among children under 10 years. The awkward gait of the toddler as well as the large head leads to falls. In addition, as children mobilize, they are also curious and begin to investigate home hazards, like cords, hot water, sharp objects, etc. Falls are the most frequent mechanism under age 5 years, but the least frequent cause of death. As children reach school age, bicycles and sports injuries become more frequent. In children over 10 years, firearms play an increased role.

The majority of pediatric trauma deaths result from head injury. The anatomy of the small child lends itself to head injury. The head consists of 20% total body surface area of the body in the first year. The higher center of gravity also leads to loss of balance and head injury. The small size of the body experiences an increased applied force as it is distributed over the relatively larger body surface area. Muscle mass is less and therefore provides less protection. Penetrating wounds may also be deeper because of the thinner muscle wall.

Risk-taking behaviors increase as children participate in school activities and begin to drive. Bicycles, pedestrians struck, and MVC are leading mechanisms in which children make risk-taking decisions. In these instances they must choose to buckle up, wear a helmet, not drink and drive, choose their speed, look both ways, watch traffic, and more.

Geriatrics

Unintentional falls are the leading cause of trauma death in individuals 65 years and older (www.cdc.gov/ncipc). It is followed closely by MVC as the second leading cause of death. Trauma is the fifth overall leading cause of death for the elderly (Ziglar et al. 2004). Burns are also frequent for the elderly usually related to alcohol use, smoking in bed, or a building fire. With decreased touch sensation and pain receptors, the elderly are also susceptible to burns from scalds and touching hot objects, for example a stove or oven.

Geriatric patients are at risk for falls caused by postural instability, decreased coordination and motor strength, and balance difficulties. Other factors include past medical history, medications,

and decreased physical reserve. Overall, the elderly are less likely to be injured than younger people but more likely to have a fatal outcome. Geriatric trauma patients are less likely to die at the scene than younger trauma patients but more likely to die in hospital with lower injury severity. Geriatric trauma patients have increased mortality and morbidity with lower severity of injury and less apparent instability (higher revised trauma scores). Comorbidities present their influence on outcome with previous myocardial infarction and pulmonary disease leading to an increased mortality after trauma. On the positive side, 80% of elderly trauma patients return to their previous state of health (ATLS 2004).

Obesity

The obese patient is particularly at risk in vehicular crashes because of the improper or lack of use of safety equipment. Most individuals require an extension on the seat belt. In addition, the placement of the belt itself may be too high across the abdomen instead of across the hips or the shoulder belt may be too close to the neck. Airbag deployment can result in increased incidence of chest injury. There is increased renal injury in abdominal trauma but less liver injury. Pelvic and lower extremity fractures are more likely. There is less facial injury. Because of a relatively unstable gait, the likelihood of falls is increased.

There is controversy regarding increased or similar mortality in obese patients versus average patients. Some studies identify obesity as an independent risk factor for mortality after trauma (Duane et al. 2006, Neville et al. 2004) and increased morbidity for bacteremia, urinary tract and respiratory infections (Bochicchio et al. 2006). Still others hold that age and injury severity are more closely associated with mortality than obesity (Alban et al. 2006).

Substance Abuse

Injury associated with substance abuse has been documented since 1500 BC in Egypt when people were warned that drinking

beer could result in falling and breaking bones (Soderstrom et al. 2001). Alcohol has been associated with up to 10% of trauma deaths, in which 40% to 50% were MVC, and up to 67% of work- and home-related incidents. Intoxication is also associated with an increased prevalence of violent acts. In situations of domestic violence, intoxication is indicated in 66% of the situations and in 33% of violence to strangers. Intoxication is also present in 58% of suicides.

Intoxicated patients have a mortality two times that of those not intoxicated (Dischinger et al. 2001). The chronic drug user has significantly more serious injuries especially in males.

INJURY PREVENTION

With the degree of injury that is preventable, trauma centers need to focus on prevention programs and healthy communities. Although sometimes difficult to measure, a program is effective if even one injury is prevented. Programs should focus on local common causes of injury. The data is obtainable through the trauma registry and local databases, such as the medical examiner and police crash database. The American College of Surgeons Committee on Trauma requires an injury prevention coordinator at Levels I and II trauma centers to demonstrate the importance of these programs in the community (ACS-COT 2006).

Methods

Injury prevention programs use the interaction of factors that result in injury as the means to investigate as well as to prevent these injuries. Factors include the following:

- Human: predisposition to injury or choices that place the person at risk
- Energy transfer: the mechanism itself and the interaction of the kinetic energy with the body
- Environment: factors within the environment that enhance or inhibit the mechanism.

Analysis of local data provides the most common mechanisms as well as the use of safety mechanisms, such as seat belts and helmets. In addition to an analysis of common injury mechanisms, a community analysis of age, cultures, home and work environments provides insight into potential mechanisms as well. Injury prevention programs should focus on common mechanisms as well as potential mechanisms, such as drinking and driving on prom night. Prevention programs can be staged into three types of programs:

- Primary: focuses on preventing the injury before it happens by means of education (eg, road edge rumble strips, turn signals on traffic lights)
- Secondary: focuses on high-risk groups and is often accomplished through manipulation of the environment (eg, softer auto interiors, antilock brakes)
- Tertiary: focuses on injury prevention intervention after trauma to decrease recidivism (eg, home safety evaluation after an elder has fallen).

Programs are developed in three venues to affect the outcomes of various mechanisms. The three methods of prevention programs include the following:

- Education
  - Most commonly offered program
  - Lecture format, brochures, ads on television or newspaper/billboards
  - Common topics include
    - Motor vehicle safety (seat belts, car seats, airbags, drinking and driving, speed, elder driving training)
    - Playground safety (structure, surface, architecture)
    - Home safety (burn, fire prevention, fall prevention/exercise)
    - Gun safety (proper handling, locks/safes)
  - Messages should be simple, clear statements
  - Multiple programs already available; research programs before developing from scratch (Table 1-3)

Table 1-3 Injury Prevention Reference

Organization	Phone/Web site	Programs
American Trauma Society	1-800-556-7890 www.amtrauma.org	Traumaroo, fall prevention, home safety, second trauma, trauma survivors network
Emergency Nurses Association	www.ena.org	ENCare
National Highway Traffic Safety Administration	202-366-1836 www.nhtsa.gov	Brochures: traffic safety; red light running; school bus safety
CDC/NCIPC	404-639-3311 www.cdc.gov/ncipc	Multiple areas of injury prevention and statistics
Consumer Product Safety Commission	1-800-638-2772 www.cpsc.gov	Baby safety showers; reports on consumer product safety and recalls
National Rifle Association	1-800-672-3888 www.nra.org	Gun safety, Eddie Eagle
National Fire Protection Agency	1-800-344-3555 www.nfpa.org	Burn safety programs; Sparky the Dog
American Burn Association	www.ameriburn.org	Burn safety programs
National Crime Prevention Council	518-842-4388 www.ncpc.org	Safety and crime prevention programs; McGruff the Dog
SafeKids	www.usa.safekids.org	Multiple safety programs for children
National Safety Commission	www.nationalsafety-commission.com	General safety information

- Environment (includes engineering in the public health model)
  - — Automatic protection provided in which the consumer does not need to make many decisions
  - — Examples include
    - Airbags
    - Antilock
    - Brakes
    - Road engineering
    - Automatic shut-off on electrical appliances
  - — As common mechanisms are researched, means of protection are developed without human intervention that can provide safety. Primarily the realm of the engineers
- Enforcement
  - — An effective means of prevention, however uses the threat of legal intervention if noncompliant
  - — Examples include
    - Seat belt and child restraint laws
    - Drinking and driving laws and penalties
    - Red light running cameras at intersections
    - Graduated licensing
  - — Although associated with fines or loss of license, in some situations the only method of increasing compliance is through enforcement.

Programs

Programs are directed to the appropriate audience and provided in a way to effect change. Not every program needs to be developed from scratch. There are programs on the market that can be adapted to the local region. Programs must include analysis of the community, distribution of the program appropriate for the community involved and in the appropriate language, and followed by an evaluation of the program for

effectiveness. A program that provides even a 10% reduction in injury would demonstrate effectiveness (Stewart 2007). The removal of even one predisposing factor, such as intoxication, speed, and lesser use of seat belt or helmet, would decrease the severity of injury (Stewart 2007). Table 1-3 lists resources for available programs.

Injury Prevention Issues

Pregnancy

As with all injury prevention, during pregnancy it is essential for the safety of the mother and the fetus. Studies show that 33 to 50% of pregnant women in MVC were not using seat belts (Ikossi et al. 2005, Metz and Abbott 2006, Minow 1999, ATLS 2008). Worn improperly, the seat belt across the abdomen can result in uterine rupture. Lap-only belts can compress the uterus and bladder. Proper use should position the lap portion of the seat belt below the "belly." Instruction in proper seat belt use as well as its importance at all times is essential during prenatal visits (Figure 1-1). Drug and alcohol abuse has also been evident in 20% to 50% of the incidences of trauma (Ikossi et al. 2005, Minow 1999). Prenatal education should consistently include the risks of substance abuse effects on the fetus as well as increased risk of injury. Fall prevention through awareness of the awkward gait will also assist the mother safely through the pregnancy period. For domestic violence, identification of the occurrence along with providing safe housing availability through social services and the legal system is the key to breaking the cycle. The National Domestic Violence Hotline is 1-800-799-SAFE (www.ndvh.org, www.CDC.gov/ncipc)

Pediatrics

Injury prevention efforts focus on the most common areas of potential injury for the age group. All age groups require motor vehicle safety. Infants up to 1 year of age and 20 lb must be in a rear-facing child seat and placed in the rear seat (NHTSA 2008). Infant car seats placed in the front can result in death from airbag deployment. The infant then graduates to a forward-facing

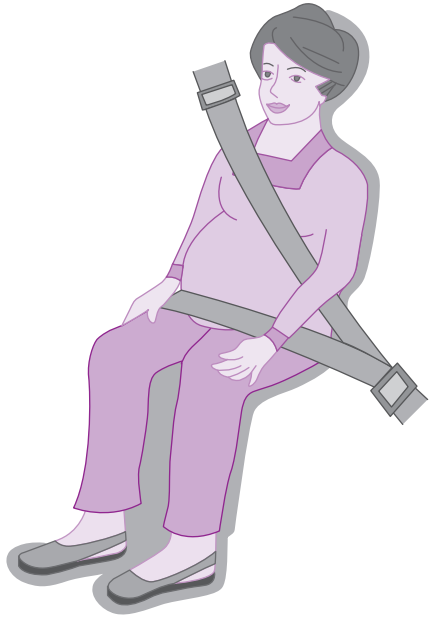

Figure 1-1 Proper seat belt use in the pregnant patient. (Illustration by Maggie Reynard.)

car seat until they are approximately 4 years or 40 lb. A booster seat is then required until approximately 8 years old. No child should be seated in the front seat until 12 years when the bones are strong enough to tolerate an impact while restrained in a seat belt. Car seat clinics with trained technicians are one of the best ways to teach car seat safety. As adolescents begin to drive, injury prevention focused on the operation of the vehicle is essential as peer pressure will test them otherwise.

Every aspect of the child's life is injury focused. Baby safety showers teach parents how to prepare the house to keep the baby safe through the early stages of mobility. Home safety protects children as they become curious and mobile. Crossing the street

safely and not chasing toys into the street prevent pedestrian events. Bicycle helmets are essential from the tricycle and on to larger vehicles even if children stay on the sidewalk. Playground safety prevents serious injury from falls. Gun safety keeps weapons away from children and locked. Bicycle rodeos and helmet give-a-ways reach out to children who may not be able to afford a helmet. Safety towns provide a means to learn traffic safety. Prom night and preprom programs provide information for teens about drinking and driving and other risk-taking behaviors.

Geriatrics

Injury prevention programs need to focus on the primary causes of injury for the elderly. There are programs designed to retest drivers older than 55 years to assess reflexes and driving skills. Seat belt education is always necessary especially since a large population of the elderly drove for many years before seat belts existed in every vehicle. Fall prevention is the topmost priority. These programs involve topics from home evaluations for safety hazards to exercise programs to maintain healthy muscles, bone, and balance. Exercise can decrease the incidence of hip fractures by up to 20% (Ziglar et al. 2004). Overall, injury prevention needs to include programs for healthy nutrition with calcium and vitamin D, and exercise to maintain a strong body with good balance and gait, as well as programs to enhance alertness and memory. Increased awareness of the most common causes of injury may decrease incidence of injury and include the following:

- Changes in medications
- Vision changes, changes to prescription of eyewear
- Decreased judgment and reaction time, especially when deciding to wear a seat belt, changing traffic lanes, and merging

Burns

Burn centers have extensive injury prevention programs and should include the elderly. Burn prevention activities have been the most effective programs as evidenced by the decreasing number of burn admissions. The local burn center is a resource for assistance with burn prevention programs.

Substance abuse

From trauma's perspective, a patient with alcoholism is three and a half times more likely to experience a second trauma. If these patients can be identified early in their trauma care, there is a perfect opportunity for intervention and prevention of recidivism. The best injury prevention is to encourage a designated driver and moderation of intake. Drug use has multiple other risks as well. Drug prevention programs with complete abstinence are the only program for these substances. As noted in Chapter 12, substance abuse screening and intervention are required by the ACS-COT (2006).

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