MECHANISMS AND DEMOGRAPHICS IN TRAUMA

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Objectives
The aims of this chapter is to put trauma in context as a major health issue and give practitioners an understanding of the underlying causes and mechanisms.

INTRODUCTION

Injury is the leading cause of death in people aged between 1 and 44 years in the United States and a leading cause of death worldwide [1]. It can be defined as a "physical harm or damage to the structure or function of the body, caused by an acute exchange of energy (mechanical, chemical, thermal, radioactive, or biological) that exceeds the body's tolerance" [2, 3]. In 2002, 33 million patients were processed by emergency departments in the United States, and 161,269 died by traumatic injury [4]. Trauma is the leading cause of years of potential life lost for people younger than 75 years and this implies a huge expense to the health care system and massive amounts of resources used for care and rehabilitation [5].

Demographics is the statistical study of human populations, especially with reference to size and density, distribution, and vital statistics. Data on the demographics of trauma in the United States have been obtained from a number of sources listed in the references to this chapter.

ALCOHOL

In a recent report from the Federal Bureau of Investigation's (FBI) Uniform Crime Reporting Program, the FBI estimated that more than 1.4 million drivers were arrested for driving under the influence of alcohol or narcotics, and an estimated 254,000 persons were injured in crashes where police reported that alcohol was present – an average of one person injured approximately every two minutes. In 2005, 21 percent of the children aged 14 and younger killed in motor vehicle crashes were killed in alcohol-related crashes.

Unintentional motor vehicle traffic-related injuries statistics:

Between 2000 and 2004, 366,021 persons suffered injuries by unintentional motor vehicle-related injuries. Of these 266,491 were vehicle occupants, 37,340 were motorcyclists, and 43,502 were pedestrians [6]. In 2005, 43,200 victims died on the highways of the United States. Safety belts are approximately 50 percent effective for preventing fatality in severe crashes. Belts save 13,000 lives each year, while 7,000 persons die because they do not use belts.

Air bags, combined with lap/shoulder safety belts, offer the most effective safety protection available today for passenger vehicle occupants. But, air bags are only to be regarded as supplemental protection to seat belts and are not designed to deploy in all crashes. Most airbags are designed to inflate in a moderate-to-severe frontal crash. In 2005, an estimated 2,741 lives were saved by air bags.

Children from 0 to 14 years are at great risk for unintentional motor vehicle-related injuries. In 2004, 1,638 children died as occupants in motor vehicle crashes (3 deaths and 386 injuries each day) and half of those killed in motor vehicle accidents were unrestrained [7]. Twenty-five percent of occupant deaths among children younger than 14 years involve a drinking driver. Restraint use among young children depends on the driver's restraint use; almost 40 percent of children riding with unbelted drivers were themselves unrestrained.
Figure 1.1. Road traffic collision overview. Important prehospital information about the collision will be lost if hospital personnel do not get a good handover from prehospital crews. Photo courtesy of PF Mahoney.

UNINTENTIONAL MOTOR VEHICLE TRAFFIC-RELATED INJURY MECHANISMS

Unless anesthesia providers are involved in prehospital care, their usual experience with trauma patients will be having them presented in the resuscitation room, packaged by prehospital ambulance crews (Figure 1.1).

To understand what has happened to the patient and to appreciate the likely injuries, it is vital to get a clear handover. Information needed includes:

- Estimated speed of vehicles involved
- Direction of impact
- Whether the vehicle rolled over
- Whether the occupants were wearing seat belts
- Whether the air bags deployed
- What damage occurred to the passenger compartment
- How long the extrication took.

To understand the magnitude of the injury, it is necessary to be able to develop a mental image of the interaction between energy and body anatomy, an intuitive concept and understanding of forces of acceleration–deceleration, and energy transferred to the body. Unintentional motor vehicle-related injuries involve a complex interaction of forces, including:

- Primary collision: impact of vehicle with another object
- Secondary collision: the casualty strikes internal parts of the vehicle that may have intruded into the passenger compartment due to the primary collision
- Damage due to organs and tissue moving within the body and tearing vessels and attachments.

Unintentional motor vehicle-related injuries usually are categorized as:

- Head-on or frontal
- Rear impact
- Side impact
- Rotational impact
- Rollover

Examples of these injury mechanisms are shown in Figures 1.2–1.5. Half of deaths are related to head-on impact, and the rest involve side impact (25%), rear impact (less than 10%), and rollover [8].

An unrestrained front seat occupant is likely to suffer one of two injury patterns in a frontal impact, depending on whether the mechanism was “down and under” or “up and over.” With the down-and-under approach the passenger slumps in the seat and the knees move forward, usually striking the underside of the dashboard. Forces are transmitted through the femurs to the hips and pelvis, resulting in fracture-dislocations and soft tissue damage below the knees. As the upper body moves forward, it hits the steering wheel, dashboard, and windshield, resulting in injury to the face, head, neck, chest, and abdomen.

In the up-and-over pattern the face and head are the first points to strike the windshield, followed by the chest. Face and head injuries result, and cervical spine injuries occur as a result of extension and/or compression. Direct injury to the front of the neck from contact with the steering wheel, dashboard, or windshield may produce severe tracheal injuries [9].

Rear impact is frequently associated with whiplash injury. Depending on the forces involved and the amount and design of
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Figure 1.3. High-energy impact removing side structures of a vehicle. Significant injuries would be expected to vehicle occupants. Photo courtesy of PF Mahoney.

In the side collision, parts of the vehicle frame intrude on the passenger compartment. Because the side of the driver’s or passenger’s body is relatively exposed and unrestrained, injury may affect any region as the body strikes the side of the vehicle. The cervical spinal column is not tolerant of lateral forces, so cervical injuries are common in side impacts [10].

Complex patterns of injury arise from vehicle rollovers. The vehicle is often severely damaged, and the risk of ejection of unrestrained passengers is usually more significant than with other types of collision.

The correct and incorrect use of seat belts may also produce specific patterns of injury. Lap belts offer little protection to the head and upper body and may cause lumbar spine and intra-abdominal injuries to the duodenum, pancreas, small bowel, spleen, liver, and gravid uterus. A diagonal shoulder belt without a lap component allows the body to slide under, possibly producing severe head and neck injuries. Wearing the diagonal component below the arm instead of above it may result in severe chest and abdominal injuries. Incorrect placement of the lap belt above the pelvis leaves the lower abdomen and lumbar spine susceptible to injury. Even the correct use of well-designed seat belts may result in injuries, the most common of which are fractures to the ribs, clavicle, and sternum [11].

MOTORCYCLE COLLISION STATISTICS

In 2005, in the United States, 4,553 motorcyclists died in motorcycle collisions and an additional 87,000 were injured. Comparing the vehicle miles traveled in 2004, motorcyclists were about thirty-four times more likely than passenger car occupants to die in a motor vehicle traffic crash and eight times more likely to be injured.

Helmet use is estimated to be 37 percent effective in preventing fatal injuries to motorcyclists. This means that for every 100 motorcyclists killed in crashes while not wearing a helmet, 37 of them could have been saved had all 100 worn helmets. Reported
Helmet use rates for fatally injured motorcyclists in 2005 were 58 percent for operators and 50 percent for passengers.

MOTORCYCLE COLLISION MECHANISMS

Injury to motorcyclists results from impact with the ground, street furniture, or the colliding vehicle. Injury can be expected to all body regions. Injuries of particular note include:

- Closed head injury
- Facial trauma
- Cervical spine fractures
- Chest injuries including injuries typical of deceleration such as aortic disruption
- Abdomen – liver and spleen injury
- Extremities – long-bone fractures.

PEDESTRIAN VEHICLE COLLISION

In 2006, in the United States, about 4,881 pedestrians were killed in traffic crashes and 64,000 were injured. On average, a pedestrian is killed in a traffic crash every 96 minutes and injured in a traffic crash every 8 minutes. Seventy percent of the pedestrians killed in 2006 were males, and 16 percent were older than 70 years. Forty-three percent of the 388 young (under age 16) pedestrian fatalities occurred in crashes between 3 p.m. and 7 p.m. and nearly one-half (48%) of all pedestrian fatalities occurred on weekends.

Adult pedestrian injury typically involves three impacts:

- Impact with the lower limbs as the impacting vehicle brakes and decelerates, lowering the front of the vehicle
- Impact with the hood of the vehicle as the casualty is thrown forward, causing head and chest injuries
- Impact with the ground, commonly causing head injury.

Pedestrian child injury is less predictable, but a typical pattern of trauma is “knocked down and run over,” resulting in chest, femur, and head injuries and secondary trauma resulting from hitting the vehicle or ground.

FALLS

Falls exceeded motor vehicle accidents as the leading cause of nonfatal injuries treated in hospital emergency departments in the United States in 2004. Falls are the most frequent cause of injuries and hospital admissions in the elderly population aged 65 years and older. Falls in the elderly are frequently associated with a concurrent medical event, such as cerebrovascular accident or myocardial ischemia. Falls involve a sudden deceleration in the vertical plane. The magnitude of injury depends on height, transference and absorption of energy, and orientation of the victim. Falls of 8 to 10 meters (25–30 feet, three stories in a building) are fatal in 50 percent of victims. If the victim is standing, foot, heel, tibia, tibia, femur, pelvis, spine, and internal organs can suffer the impact. Head-first impact can produce facial-cranial injury, lesions of neck, cervical spine, shoulders, and pelvis.

TRAUMATIC BRAIN INJURY (TBI)

Traumatic brain injuries contribute to a substantial number of deaths and cases of permanent disability annually. Of the 1.4 million who sustain a TBI each year in the United States, about 50,000 die, 235,000 are hospitalized, and 1.1 million are treated and released from an emergency department.

Among children aged 0 to 14 years, TBI results in an estimated 2,685 deaths, 37,000 hospitalizations, and 435,000 emergency department visits annually [12]. The leading causes of TBI are falls (28%), motor vehicle-traffic crashes (20%), struck by/against events (19%), and assaults (11%) [13].

FIRE AND BURN DEATHS

Deaths from fires and burns are the fifth most common cause of unintentional injury deaths in the United States [14]. The average extent of a burn injury admitted to a burn center is about 14 percent of total body surface area (1991–93) while burns of 60 percent total body surface area or more account for 4 percent of admissions.

Most victims of fires die from smoke or toxic gases and not from burns [15]. Smoking is the leading cause of fire-related deaths, and cooking is the primary cause of residential fires [16]. Approximately half of home fire deaths occur in homes without smoke alarms [17].

FIRE COSTS

In 2005, residential fires caused nearly $7 billion in property damage [12]. Fire and burn injuries cost about $8.5 billion each year [5]. Fatal fire and burn injuries cost $3 billion. Hospitalized fire and burn injuries total $1 billion.

FIREARM – GUNSHOT

In 2003, 30,136 persons died from firearm injuries in the United States, accounting for 18.4 percent of all injury deaths. Males had an age-adjusted rate that was 6.8 times that for females, the black population had a rate that was 2.1 times that of the white population, and the non-Hispanic population had a rate that was 1.3 times that of the Hispanic population.

In 2004, the number of deaths due to homicides was 16,611, of which firearms homicides caused 11,250 deaths [19]. Homicide is the leading cause of death for black males aged 15 to 24 years, and 73 percent of homicides were firearm related.

School shootings are devastating events that raise many concerns about the safety of the young population. However, the vast majority of youth homicides occur outside school hours and property. Fewer than 1 percent of the total number of children and youth homicides (2–19 years of age) is related to school shootings.
Figure 1.6. These three pictures show a bullet entry wound (a), the path through the liver (b), and the exit wound (c). The extent of the injury only becomes clear at surgery or at forensic examination. On first inspection it is often difficult to be confident about which is the entry and which is the exit wound. Photo courtesy of PF Mahoney.

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PENETRATING TRAUMA MECHANISMS

Low-Energy Transfer Sharp Implements

Knives: The main issue to appreciate when managing knife wounds is that tissue is elastic. The dimensions of the observed wound in a patient may not relate to the weapon used. A knife assailant may turn the blade in the target’s body, causing increased damage as structures are deliberately cut.

Swords: Different swords are designed to be used in different ways. For example, a sharp Samurai sword is designed with a cutting edge and if used in this fashion will produce injury different from a sword designed for thrusting, or another type, the broad sword.

Projectiles

Arrows: In general, injuries from arrows can be considered as “low-energy transfer” wounds and the area of injury is closely related to the arrow trajectory. This is not to dismiss how damaging arrows from a powerful bow or bolts from a crossbow can be.

Bullets: Modern firearm ammunition is a combination of a projectile (the bullet) and a case. The bullet is held in the front end of the case. The case contains propellant. When this is initiated the bullet is propelled down the barrel of the weapon. Many weapons have grooves inside the barrel that cause the bullet to spin, giving a degree of stability as it flies, although bullets may become unstable in flight and "tumble.” The wounding effect on tissue is a combination of:

- The properties of the tissue. Elastic tissue is pushed away; nonelastic tissue may shatter.
- The energy of the projectile. Kinetic energy of the projectile equals half the mass of the bullet times velocity squared \((\frac{1}{2} M \times V \times V)\).
- The energy transferred by the projectile to the tissue. This varies according to how the bullet strikes: nose first or side first. A larger surface of the bullet striking usually means more energy given up.
- Whether or not the projectile breaks up in the tissue. The resulting fragments cause their own wounds.
- Vital structures hit (Figure 1.6, see also color plate after p. 284).

There is an arbitrary division between high-velocity (2,000–2,500 feet per second) and low-velocity bullets, but a better terminology is “high- and low-energy transfer wounds” depending on how much energy is dumped into the tissue,
which in turn is influenced by the preceding factors. Projectiles moving at more than 1,000 feet per second are associated with a significant "temporary cavity" in tissue – that is, the kinetic energy given up to the tissues forces them away from the missile tract – and this can be many times the size of the permanent cavity left by the missile. This temporary cavity generally lasts only a few milliseconds. Dirt and clothing can be carried into the wound by the projectile and drawn in by the vacuum effects of the temporary cavity, leading to wound contamination.

Types of Bullets
Some broad examples are:

- Full metal jacket: metal casing around a lead core. A nonexpanding round that produces a deep wound.
- Jacketed hollow point: an exposed hollowed lead tip allows expansion of the round on impact. Less tissue penetration than full metal jacket but more energy transfer to tissue.
- Soft point: exposed lead tip allows rapid expansion.
- Altered ammunition: actions taken after ammunition has been manufactured to increase the wounds produced, for example, altering the shape or structure to increase tumble or fragmentation in the body. (Military use of altered and expanding ammunition was limited by the 1899 Hague Convention.)

Explosive Munition Injury
The injury produced by a bullet is the result of a complex interaction between the bullet and tissue. Injury produced by an explosive device is also the result of complex interactions that can be broken down into a number of mechanisms.

Explosives are categorized as high order or low order depending on how rapidly they change their state once initiated. High-order explosives undergo almost instantaneous change from solid to gas, rapidly releasing energy, and are associated with sudden increases in pressure and a supersonic shock wave/shock front. Low-order explosives change less rapidly and are not as associated with pressure wave transfer to tissue.

Blast injury has been classified as follows:

Primary: due to the actions of the blast or overpressure wave. This can completely disintegrate a casualty. The blast wave interacts with the body or component tissue, dumping energy into the tissue and producing stress waves that cause microvascular injury and shear waves that produce asynchronous tissue movement, which causes tearing.

Secondary: due to fragments projected by the energy of the explosion. Fragments can be "natural" from the random fragmentation of the bomb's components, or "preformed" from notched wire, metal balls, or squares packed into the bomb. These cause multiple penetrating injuries.

Tertiary: due to the casualty being thrown/displaced by the explosion or injured due to the structural collapse. This is generally "blunt" injury.

Quaternary: all other effects, including fires from the explosive components or from ignited fuel, toxic effects of fumes, and exacerbation of medical conditions.

There is a question as to whether human tissue from homicide bombers or bombs in crowded places that ends up embedded in another victim should be classified as a separate wounding mechanism.

Practically, casualties will often have complex combinations of these mechanisms.

- A casualty in a military vehicle blown up by a bomb may be sheltered from the worst of the fragments but injured by the blast wave and fires within the vehicle.
- A soldier injured by a roadside bomb may escape the blast effect but suffer multiple penetrating injuries from fragments.

This can lead to conflicting requirements during surgery and anesthesia and will be considered further in the chapter on military and field anesthesia.

SUMMARY
This chapter has provided an introduction to trauma mechanisms and the wider impacts of trauma on the population and the economy. Clinical issues will be expanded in the relevant chapters throughout the book.

MULTIPLE CHOICE QUESTIONS
1. Which of the following is correct?
   a. Trauma deaths occur equally in all age groups.
   b. Sporting accidents are the leading cause of death in people older than 75 years.
   c. Falls in the elderly are often associated with events such as transient ischemic attacks or myocardial ischemia.
   d. Alcohol use is not associated with traffic collisions.

2. With regard to motorcycle collisions, which of the following is correct?
   a. When compared mile for mile, motorcycles are a safer mode of transport than cars.
   b. In motorcycle crashes only the riders’ limbs suffer injury.
   c. It is safe to use narcotics and ride motorcycles.
   d. Wearing a helmet can significantly reduce death from head injury in motorcyclists.

3. Considering children injured in road collisions, which of the following is correct?
   a. Children are rarely injured in road accidents.
   b. Alcohol use by a driver is a significant cause of children being injured both as passengers and as pedestrians.
   c. Children do not need to wear seat belts.
   d. Children have more flexible bones than adults so are not as badly hurt if hit by a car.
4. Concerning adult pedestrians hit by cars, which of the following is correct?
   a. Adult pedestrians typically suffer three impacts when hit by a car – hit in the lower limbs, impact with the vehicle hood, then a further impact with the road.
   b. Weekends are the safest time for pedestrians.
   c. Males and females are injured equally in pedestrian collisions.
   d. Vehicle speed has no influence on pedestrian injuries suffered.

5. Regarding death and injury caused by fires, which of the following is correct?
   a. Carbon monoxide and flames cause an equal number of fatalities.
   b. Smoking at home when under the influence of alcohol is safe.
   c. Fire and burn injuries cost the United States about $1 million every year.
   d. Approximately half of home fire deaths occur in homes without smoke alarms.

6. Which of the following statements about firearm incidents is correct?
   a. Firearm deaths in the United States affect males and females equally.
   b. Firearm deaths in the United States affect all ethnic groups equally.
   c. Firearms deaths in the United States affect all age groups equally.
   d. Less than 1 percent of the total number of children and youth homicides (5 to 19 years of age) are related to school shootings.

7. Concerning penetrating trauma, which of the following is true?
   a. All bullets have the same kinetic energy.
   b. Expanding ammunition was endorsed by the 1899 Hague Convention.
   c. The properties of the tissue struck by a bullet influence the injury produced.
   d. The kinetic energy of a bullet is given by its height multiplied by its weight.

8. Regarding knife injuries, which of the following is true?
   a. You can guess the length of the knife used to cause a wound by looking at the wound.
   b. Knives used for stabbing and swords used for slashing always produce identical wounds.
   c. If a patient presents with a knife in situ, wait until the patient is in the operating room before the surgeon takes it out.
   d. Knives always do more damage to people than bullets.

9. Concerning explosive injury, which of the following is true?
   a. Low-energy explosives cause a huge shock wave.
   b. A casualty in a vehicle will always be protected from the heat of an explosion.
   c. The effects of fires in an explosion are termed primary blast injury.
   d. The effects of fragments in an explosion are termed secondary blast injury.

10. With regard to trauma mechanisms, which of the following is true?
    a. Injuries after falling from more than twenty feet are generally very minor.
    b. Traumatic brain injury rarely occurs in the United States.
    c. The average size of burns admitted to burn centers is about 80 percent.
    d. Dirt and clothing fragments carried into a bullet wound are sources of contamination.

ANSWERS
1. c
   2. d
   3. b
   4. a
   5. c
   6. d
   7. c
   8. d
   9. b

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TRAUMA AIRWAY MANAGEMENT

William C. Wilson

Objectives
1. Review the major considerations and tools needed for trauma airway management.
2. Characterize the difficult airway in trauma.
3. Evaluate the American Society of Anesthesiologists’ difficult airway algorithm with regard to trauma.
4. Provide a plan for managing common trauma difficult airway scenarios.

INTRODUCTION

Airway management disasters account for a large proportion of malpractice lawsuits in the American Society of Anesthesiologists’ (ASA) Closed Claims database [1]. Airway loss is a major cause of preventable prehospital death in trauma patients [2]. Trauma airway management is complicated because of associated pathology and suboptimal intubating conditions, and also because complete preintubation evaluation and planning is rarely possible. Furthermore, trauma patients are at increased risk for hypoxia, airway obstruction, hyperventilation, hypotension, and aspiration.

A significant reduction in airway management claims has occurred over the past decade due to the introduction of the ASA difficult airway algorithm, which institutionalized the need for airway evaluation, awake intubation techniques, and the use of back-up rescue modalities such as laryngeal mask airway (LMA), esophageal-tracheal-combitube (Combitube), and transtracheal jet ventilation (TTJV) [1]. It is therefore logical that incorporation of the ASA difficult airway algorithm, with certain minor modifications, can likewise improve safety during trauma airway management.

This review of airway management for trauma begins with a survey of the equipment and drugs that should be prepared ahead of time, defines and characterizes the “difficult airway,” and describes the principles of airway evaluation and management for the trauma patient. Proper evaluation and prioritization of treatment are emphasized throughout this chapter, with awake intubation techniques recommended for difficult airway management in cooperative, stable trauma patients. Emergency airway adjuncts such as the LMA and Combitube may be required to rescue the cannot intubate–cannot ventilate situation. Specific tips are provided regarding the successful techniques and pitfalls of fiberoptic bronchoscopy, and the fiberoptic bronchoscopy technique is emphasized where appropriate throughout this chapter.

EQUIPMENT AND DRUG PREPARATION

Regardless of the urgency associated with any particular intubation event, several key drugs and airway management tools are universally required; these should be available (and guaranteed to be in working order) for the physician providing airway management for the trauma patient. Essential emergency airway equipment items are listed in Table 2.1 and include: (1) an oxygen (O2) source and various types of administration devices; (2) an assortment of oral and nasal airways, along with a bag-valve-mask ventilation device capable of applying positive pressure ventilation (and able to deliver 100% O2); (3) intubation equipment (including laryngoscopes, styletted and pretested endotracheal tubes [ETTs]); (4) suction tubing and a tonsil tipped suction device; (5) a functioning intravenous (IV) catheter; (6) prelabeled syringes containing induction and resuscitation drugs including vasopressors and inotropes; (7) appropriate monitors and intubation detectors (as will be described shortly). All of the aforementioned equipment (except for the
Table 2.1: Essential Emergency Airway Equipment Contained in Portable Storage Unit for Trauma Resuscitation

<table>
<thead>
<tr>
<th>Equipment Category</th>
<th>Specific Emergency Airway Device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen</td>
<td>Oxygen (O₂) inflow tubing and O₂ source.</td>
</tr>
<tr>
<td>Intubation</td>
<td>Laryngoscope with new tested batteries. #3 and #4 Macintosh blades with functioning light bulbs. #2 and #3 Miller blades with functioning light bulbs. Endotracheal tubes – various sizes styledt with balloon tested. Tracheal tube guides (gum elastic bougie, semirigid stylets, ventilating tube changer, light wand). Flexible fiberoptic intubation equipment. Retrograde intubation equipment. Adhesive tape or umbilical tape for securing ETT.</td>
</tr>
<tr>
<td>Suction</td>
<td>Yankauer, endotracheal suction.</td>
</tr>
<tr>
<td>Monitor</td>
<td>P&lt;sub&gt;e&lt;/sub&gt;O₂, pulse oximeter, esophageal detector device.</td>
</tr>
<tr>
<td>Drugs</td>
<td>IV induction and paralytic medication. Topicalization drugs. deVilbiss sprayer for application of topical drugs. Resuscitation drugs (epinephrine, atropine, etc.).</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>Various syringes, needles, stopcocks, IV connector tubes.</td>
</tr>
</tbody>
</table>

O₂ source) should fit into a portable storage unit (i.e., Code Bag) for trauma resuscitation. In austere environments, small tanks of O₂ will also need to be transported to the site of emergency airway management. The importance of each of these essential airway management devices and drugs will be reviewed in this section.

Oxygen: Critical During Trauma Airway Management

Advanced Trauma Life Support® (ATLS®) begins with assessment and management of the airway and breathing, the top two priorities in the ABCDEs of the primary survey. As soon as a trauma patient is encountered in the field or in the trauma bay, O₂ is immediately applied. Furthermore, O₂ should be administered throughout the trauma assessment and treatment phase.

Hypoxemia is a constant threat in trauma and critical illness due to disease processes that cause respiratory failure and those associated with injury. In addition, 100 percent O₂ should be administered for three to five minutes immediately preceding airway management (i.e., preoxygenation) to increase the duration of adequate O₂ saturation during the period of postinduction apnea.

Treatment of Hypoxemia

Clinically, the term hypoxia denotes decreased O₂ tension at the tissue level. Hypoxemia is defined as decreased O₂ tension in the arterial blood (Pao₂). In trauma scenarios, when tissue hypoxia occurs, hypoxemia is nearly always present.

Hypoxemia has eight major causes. The first five etiologies are related to the atmosphere (low partial pressure of inspired O₂) or the lungs (hypoventilation, ventilation-perfusion mismatch, right-to-left transpulmonary shunt, and diffusion abnormalities). The next two causes of hypoxemia involve delivery of O₂ to the tissues (i.e., low oxyhemoglobin or low cardiac output). The final cause of hypoxemia is termed “histocytic,” denoting a problem in O₂ utilization at the tissue level, usually due to the poisoning of the mitochondrial electron transport chain, as seen with cyanide or carbon monoxide toxicity. Patients suffering from all of these eight causes of hypoxemia will benefit from the administration of 100 percent O₂.

Preoxygenation: Maximizing Arterial Saturation during Apnea

During trauma airway management, O₂ is administered prior to intubation in a process called preoxygenation. Optimum preoxygenation requires that 100 percent O₂ be delivered by a tight-fitting mask during spontaneous ventilation for three to five minutes prior to administering drugs that cause apnea. If the time does not allow for a full five minutes of preoxygenation, the patient should be instructed to take four to eight vital capacity breaths; this will increase O₂ stores, though not to the same level as a full five minutes of preoxygenation. The