TRAUMA SERIES:
CHEST INJURIES

Jassin M. Jouria, MD

Dr. Jassin M. Jouria is a medical doctor, professor of academic medicine, and medical author. He graduated from Ross University School of Medicine and has completed his clinical clerkship training in various teaching hospitals throughout New York, including King’s County Hospital Center and Brookdale Medical Center, among others. Dr. Jouria has passed all USMLE medical board exams, and has served as a test prep tutor and instructor for Kaplan. He has developed several medical courses and curricula for a variety of educational institutions. Dr. Jouria has also served on multiple levels in the academic field including faculty member and Department Chair. Dr. Jouria continues to serves as a Subject Matter Expert for several continuing education organizations covering multiple basic medical sciences. He has also developed several continuing medical education courses covering various topics in clinical medicine. Recently, Dr. Jouria has been contracted by the University of Miami/Jackson Memorial Hospital’s Department of Surgery to develop an e-module training series for trauma patient management.

Dr. Jouria is currently authoring an academic textbook on Human Anatomy & Physiology.

ABSTRACT
Over 100,000 U.S. deaths each year can be attributed to trauma, and a significant portion of those traumatic injuries are to the chest. Chest trauma is a broad category of potentially life-threatening injury that encompasses both blunt and penetrating injuries. Treatment for these injuries needs to be swift in order to ensure the best possible outcome. Failure to properly diagnose and treat chest injuries in a timely manner can have devastating effects, including thoracic lesions, sepsis, and death. This course offers a look into the basic physiology of the thorax, chest trauma pathophysiology, and the effective management of chest trauma in the urgent setting.

**Continuing Nursing Education Course Director & Planners**

William A. Cook, PhD, NurseCe4Less.com Director

Doug Lawrence, MS, Nurse Ce4Less.com Webmaster Course Planner

Susan DePasquale, CGRN, MSN, Nurse Ce4Less.com Lead Nurse Planner

**Accreditation Statement**

This activity has been planned and implemented in accordance with the policies of NurseCe4Less.com and the continuing nursing education requirements of the American Nurses Credentialing Center's Commission on Accreditation for registered nurses.

**Credit Designation**

This educational activity is credited for 8 hours. Nurses may only claim credit commensurate with the credit awarded for completion of this course activity.
It is the policy of NurseCe4Less.com to ensure objectivity, transparency, and best practice in clinical education for all CNE educational activities. All authors and course planners participating in the planning or implementation of a CNE activity are expected to disclose to course participants any relevant conflict of interest that may arise.

**Statement of Need**

National data identifies a significant proportion of trauma cases reported every year involve injuries to the chest. Nurses are essential members of the trauma and critical care teams. Educating nurses to provide competent trauma care is an essential requirement that significantly reduces morbidity and mortality of trauma patients with injuries to the chest.

**Course Purpose**

This course will provide advanced learning for nurses interested in the management of the trauma patient with a chest injury.

**Learning Objectives**

1. Describe the common etiology of chest trauma.
2. Explain the pathophysiology of chest trauma.
3. List common injuries to the chest wall.
4. Identify common types of pulmonary and pleural space injuries.
5. Recognize the impact of chest trauma on the tracheobronchial region.
6. Define common types of cardiac injury.
7. Identify the two categories of chest injury.
8. Recognize the visual signs of a blunt chest injury.
10. Identify common treatments for blunt chest injuries.
11. Explain common treatment strategies for penetrating chest injuries.
12. Describe recovery procedures for chest injuries.
13. Identify the most common cause of penetrating chest injuries.
15. Describe the purpose of intubation and ventilation in patients with cardiac injury.

**Target Audience**

RNs, LPNs and Registered Nurse Practitioners

**Course Author & Director Disclosures**

Jassin M. Jouria, MD has no disclosures

William S. Cook, PhD has no disclosures

Doug Lawrence, MS has no disclosures

Susan DePasquale, CGRN, MSN has no disclosures

**Acknowledgement of Commercial Support:**

There is no commercial support for this course.

**Activity Review Information:**

This course has been peer reviewed by Susan DePasquale, CGRN, MSN. Review Date: July 27, 2013.

**Release Date:** August 1, 2013  
**Termination Date:** August 1, 2016

**INTRODUCTION**
We live in a fast moving world dominated by various forms of vehicles, for the greater part motorized. Our public health systems have brought us a long way towards the elimination of the endemic and pandemic infection diseases that were the killers of mostly younger persons. Our public health systems have also done much to reduce the numbers of fatalities in the residual dominant killer of younger persons, namely motor vehicle accidents. But just as there was resistance to mass vaccinations and inoculations, there is resistance to the simple highly effective protective measures of seat and lap belts for cars, helmets for bicyclists, and zero blood alcohol levels for all on the road. This plague of road injuries presents a great public expense in care of the injured, an expense measured in grief as well as in money. Although most of the deaths are related to head injuries, the chest protects the vital organs of heart and lungs, and injuries to the chest are major factors in the death rate. This course examines the types of injuries currently experienced in our society, how they are diagnosed and how they are treated.

**ANATOMY OF THE THORACIC CAGE**

The skull is a box designed to protect the body's most vulnerable organ – the brain. The thorax is also a box, designed to protect the next most important organs – the heart and lungs. But there's a compromise in that the chest has also to be like an accordion, a squeeze-box, and has an element of mobility. To remind us we are only slightly advanced from the segmental snake, the segmental nature of our bodies is best illustrated in the thorax. There are twelve segments. Each segment has a vertebra (variously called thoracic or dorsal, and numbered 1 to 12 as either D1 or more usually T1. Each segment has a rib, a nerve and an artery, named intercostal because they run between the ribs. The ribs are all joined to the vertebrae posteriorly at synovial joints; the upper seven ribs are joined to the sternum in front, also at joints, but the ends of the ribs, from above down, are increasingly formed of stiff costal-cartilage. The lowest 5 ribs
do not join the sternum, but costal cartilages of ribs 8-10 fuse together completing the lower thoracic margin, and ribs 11 & 12 have unattached anterior tips, all quite easily palpated. The thorax is built like an old-fashioned chimney hearth, wide below, tapering to a narrow upper end. The “roof”, covered by the dense supra-pleural membrane (aka Sibson’s fascia), and the domed diaphragm forms the floor of the thorax. Like all vertebrates, there are three layers of muscles. The outermost attaches the arm to the torso, which permits free movements of the arm or (should we wish to revert to the trees) an ability to pull the body up by the arms. The middle layer is mixed with the ribs and has muscle fibers in two sheets going at right angles to each other. It is these that allow the ribs to move up and down, expanding and contracting the internal volume of the thorax; and, the innermost layer has migrated and has become the diaphragm.

**NORMAL PHYSIOLOGY** 1,2,3,4,5

Here are described the simple functions of the lungs which through the acts of respiration provide oxygen for metabolism in the cells of the body and remove their waste product of carbon dioxide. Anyone who has read a report on pulmonary function will be aware of the numerous factors that are measured for the Respiratory Therapists 6 and/or Respirologist 7 to make their decisions on diagnosis and appropriate treatments.

**Pulmonary Ventilation** 8
Flow of air from the exterior of the body to the interior of the lungs, followed in the reverse direction of air expelled from the lungs back into the air around the body.

**Diffusion of gases**
Oxygen passes through the wall of the alveolus and into the capillaries; carbon dioxide leaves the capillaries, passes through the alveolar wall and into the air space.

**Transport of gases**
Oxygen is carried through the body, mostly by the red cells, to a lesser extent by solution in the plasma and other body fluids.
Regulation of Ventilation

Although one may deliberately breathe rapidly or slowly and override the automaticity of breathing, one cannot voluntarily cease breathing, and while we are asleep, or even unconscious, breathing continues, regulated directly by the autonomic nervous system, and remotely by the central nervous system.

Mechanics of Ventilation

Air enters and leaves the lungs in the same manner as it passes in or out of mechanical bellows or a “squeeze-box.” If the inner volume of the chest cavity increases, air is passively drawn in – when it decreases, air is expelled.

Internal capacity of the thorax, hence lungs, is accomplished in light breathing by flattening the convex dome of the diaphragm; in heavier breathing the ribs are elevated thereby increasing thoracic volume, effected primarily by the external intercostal muscles. In their resting position the ribs slope down, in the expanded thorax they are more horizontal, and the sternum is carried forward, increasing the antero-posterior diameter of the chest. In stressed breathing, as after running, or in a patient in respiratory distress, secondary muscles of respiration come into play. The “out of breath” athlete puts his hands on his hips so the pectoral muscles, which generally lift the arms on a fixed chest, now do the reverse, they lift the chest on fixed arms. In more severe distress, even neck muscles like sternomastoid and scalenes are recruited to lift the thoracic cage. Expiration is usually passive, by a relaxation of the muscles used in inspiration. Forced expiration uses the muscles of the abdominal wall to force up the dome of the diaphragm and the internal intercostals to pull down the rib cage. Heavy lifting requires the subject to hold his breath – the tensed abdomen forms a balloon under the flexed spine to support it; persons who cannot hold their breath or who have weak abdominal muscles, are unable to lift objects of any real weight.

Pleural Pressure

The only point of attachment of the lungs to other structures is to the trachea by the bronchi, they are otherwise “free floating” balloons in the thoracic cage. The outer
surface of the lung covered with its visceral pleura membrane is separated by a thin layer of slightly viscous pleural fluid from the parietal layer that lines the thoracic cavity. The pleural fluid prevents friction between the layers as they move on each other in normal respiration. There is in normal life a slightly negative pressure in the space between visceral and parietal layers of pleura, caused by normal drainage of the pleural fluid into lymph channels. At full expiration, with the chest cage collapsed downwards, the pleural pressure is minus 5 cms of water; as the cage is elevated, and the diaphragm is depressed, the negative pressure increases to 7.5 cms water, and the two layers of pleura still remain “glued” together by this negative pressure. The opposite, of course, occurs in the phase of expiration.

**Alveolar Pressure**

When the chest is still, and the mouth open, the air pressure inside the alveolar sacs is the same as outside the body, i.e. atmospheric pressure. As the thoracic cavity expands, alveolar pressure falls to minus 1 cm of water, which (although it doesn’t sound like much) will in two seconds draw half a liter of air into the lungs. In expiration, the reverse occurs, alveolar pressure rises to a positive 1 cm of water, and air is passively expelled.

**Transpulmonary (Recoil) Pressure**

The difference at any point in time between pleural pressure and alveolar pressure represents the elastic forces of the lung tissues.

**Lung Compliance**

This is the measure to which the lung expansion “complies” with, or mirrors, the expansion of the thoracic cavity. Normally there are 200 ccs air inspired for each 1 cm H$_2$O of increase in transpulmonary pressure. It is a measure of the elasticity of the lung tissues (one third of the elastic effect), but also of the important elastic effects of the fluid on the surface of the alveoli, which make up two thirds of the total elastic forces in the lungs.
Surface Tension Elastic Force and Surfactant \[^{12,13,14}\]

Water molecules are electrically charged, they have positive and negative poles, thus they clump together (as in rain drops), and this clumping together creates a force; inside the lung the surface water on the alveolar sacs contracts as a layer and partially contacts the sac, passively forcing out air. Specialized cells in the alveolar membrane secrete a combination of chemicals, which spread over the surface water of the alveoli and reduce the surface tension to a half or a tenth of what would otherwise be an unaffected force. The effect of surfactant is to lower very significantly the force needed to compete against surface tension and get air into the alveolar sacs.

Pulmonary Volume

- **Tidal Volume** (\(V_T\))
  
  Volume of air with each breath either in or out, not both, and average is 500 ccs.

- **Inspiratory Reserve Volume** (IRV)
  
  After a normal inspiration this is the extra amount that can be drawn in with maximum effort, average is 3 liters.

- **Expiratory Reserve Volume** (ERV)
  
  After a normal expiration, the amount that can be forced out with greatest effort, average is just over a liter.

- **Residual Volume** (RV)
  
  What is still remaining in the lungs after the expiratory reserve volume is removed, average is slightly more than the expiratory reserve volume.

- **Pulmonary Capacities**
  
  The above volumes are of less practical use individually than collectively, and from the clinical point of view, pulmonary capacities are more likely to be considered.
• **Inspiratory Capacity (IC)**
  This is the sum of tidal volume and inspiratory reserve volume, the amount taken in after normal expiration and with maximal inspiration, and averages 3½ liters.

• **Functional Residual Capacity (FRC)**
  Expiratory reserve volume plus residual volume is the air remaining in the lungs after normal expiration, averages 2300 ccs.
  \[ \text{FRC} = \text{ERV} + \text{RV} \]

• **Vital Capacity (VC)**
  Inspiratory reserve volume plus tidal volume plus expiratory reserve volume, averages 4½ liters.
  \[ \text{VC} = \text{IRV} + V_T + \text{ERV}; \text{VC} = \text{IC} + \text{ERV} \]

• **Total Lung Capacity (TLC)**
  Maximum capacity with greatest effort, vital capacity plus residual volume, averages nearly 6 liters.
  \[ \text{TLC} = \text{VC} + \text{RV}; \text{TLC} = \text{IC} + \text{FRC} \]

• **Gender and Size**
  On average, lung capacities are higher in men, higher in big persons, and higher in athletic persons.

• **Minute Respiratory Volume**
  The amount of air moved in one minute: tidal volume multiplied by respiratory rate – for example 500ccs times 12, or 6 liters per minute.

• **Alveolar Ventilation**
  Defined as the rate at which new air reaches the surfaces where exchange of gases takes place. The apparent conundrum is that in quiet respiration (e.g. at rest or asleep) the amount of tidal air is insufficient to enter the alveolar sacs.
The solution is that the gas molecules are exchanged by diffusion, the kinetic energy of the molecules keeps them in motion, and for the short terminal distance into the alveolar sac the exchange of gases is by diffusion of molecules covering the distance required in a fraction of a second.

- **Dead Space Air**
  All the portion of the respiratory system where exchange of gases is not taking place, from the mouth to the lower respiratory tract; the average is 150 ccs. To measure the oxygen content of dead space air, the beginning of expiration, gives an incorrect measure of the gas exchanged in the lungs.

**PATHOPHYSIOLOGY**

Injuries of specific structures are described in relevant sections. Here we describe the general aspects of pathology of the respiratory tract, recognizing that persons with pre-existing respiratory conditions are as liable to be injured as any other person.\(^{15, 16, 17}\)

**Restricted flow of air**

The “A” of the ABC on initial examination in the field (don’t wait until triage in the ER!) means “Airway.” The search is for obstruction by foreign body in the mouth, including displaced dentures. The first point of narrowing of the respiratory tract is at the vocal cords, obstruction may occur from a foreign body (FB) sitting on top of the cords and readily seen with the laryngoscope. If it has passed into the trachea it will only obstruct if it is large and totally blocking the passage of air, the trachea and bronchi are not contractile; removal of an FB, unless spontaneous, or with a Heimlich\(^{18}\) maneuver, will require bronchoscopy. Obstruction at this level is indicated by *stridor*, often a quite loud noise on inspiration, in a distressed patient.\(^{19, 20, 21, 22}\)

The first contractile part of the system is at the bronchioles; obstruction here may cause a wheezing (noise on expiration) as in asthma.\(^{23, 24}\) The degree of obstruction is indicated by the pulse oximeter,\(^{25, 26}\) and there is usually a history of asthma obtainable.
The exchange of gases at the level of the alveolar sac may be obstructed by fluid in the lungs, filling the alveolar sacs. Atelectasis\(^{27,28}\) is the collapse of the alveoli in a segment of lung after the tube leading to them has been obstructed; the air is absorbed and the alveoli do not readily re-expand even after the obstruction has been removed.\(^{29}\)

**Restricted flow of blood**

There are two sources of blood supply to the lungs, the bronchial arteries supply the tissue with their normal requirement of oxygen to function; the much larger pulmonary arteries lead from the heart and are concerned with re-oxygenation of blood. Although designated as “artery” their content is venous quality, deoxygenated, blood. Blood clots\(^{30,31}\) are particularly likely to occur in the immobile, injured, shocked patient. The clot forms in the veins of the legs and/or pelvis, if it breaks loose it is known as an embolus; it passes in the inferior vena cava to the right side of the heart, from there via the pulmonary artery to the lungs as a pulmonary embolus (PE). A section of the lung, depending where the clot lodges and its size, is deprived suddenly of the pulmonary circulation and death may ensue.\(^{32,33,34}\) There are other forms of emboli, such as air embolus\(^{35}\) which is usually caused by something the doctor was doing (iatrogenic) since air has been injected, or in divers with air under pressure\(^{36}\), fat embolism\(^{37,38}\) common in shocked patients, and amniotic when amniotic fluid enters the maternal blood stream.\(^{39,40}\)

**Infection and Sepsis**

The word “pneumonia”\(^{41}\) has been around so long it isn’t likely to be changed, but it is really a pneumonitis, or lung infection. Any injury to the lungs is likely to be followed by a low-grade infection, generally called a bronchopneumonia.\(^{42}\) This is particularly likely to occur in old and frail persons who fall, break one or more ribs, are treated sympathetically with a chest belt\(^{43}\) to relieve pain by restricting breathing; pneumonia and death soon follow. An abscess\(^{44}\) may result from a penetrating injury, or from treatment. Apart from antibiotic treatment (antibiotics cannot penetrate into an abscess) they may require evacuation by needle, thoracoscopy or tube drainage. The pleural space may become infected, setting up a septic pleurisy.\(^{45}\) Tuberculosis\(^{46}\) remains a
worldwide problem and the patient, particularly if an immigrant, may suffer from chronic tuberculosis, or the lungs on X-ray may show confusing evidence of treatments no longer common in North America.47

**Space-occupying lesions**
Lung tumors of many kinds, mostly malignant, are not uncommon and may present a confusing radiologic picture.48 49

**ETIOLOGY**

**Motor Vehicle Accidents**

*History*
The first human fatality associated with a motor vehicle is reported as a pedestrian killed in 1899;50 our relationship with motorized vehicles has continued, advanced to cause many more deaths, and mankind is now learning belatedly to defend itself by protective mechanisms such as seat belts. But injuries incurred in road collisions causing trauma are increasing in numbers and severity every year. Perhaps because of the elimination of many diseases, injury is now the most common cause of death in young adults in the western world. Consequently, injuries (or trauma to use the medical word) use up a disproportionate and quite avoidable proportion of the health care budgets personal and national. This is becoming particularly noticeable in the developing world, which is rapidly becoming more motorized, but is the least conscious of protective driving skills, rules of the road and personal safety structures. Without consideration to the origin of the thoracic trauma, 15% of children do not survive their injuries. According to the analysis of the National Pediatric Trauma Registry, almost half of the deaths in those with blunt injury were due to concomitant brain injury, whereas in children whose thoracic injury was due to penetrating trauma, most deaths were due to the chest injury itself.51

*Statistics*
The statistics are irrefutable that motor vehicle collisions have become the leading cause of death in young persons in the United States.52 In 2009 more than two million
drivers and passengers were treated in emergency departments as the result of motor vehicle crashes,\(^5^3\) and it is the age group of 18 to 24 that has the highest rate of trauma due to motor vehicle collisions (MVCs).\(^5^4\) All of this comes with a price tag – a great deal of personal grief and a great deal of expense in costs of treatment, often a lifetime of treatment, for pedestrians, passengers as well as drivers; estimated in 2005 at $70 billion.\(^5^5\)

**Worldwide figures**\(^5^6\)

In one recorded year an estimate was made in 1990 that across the world five million people had died from their MVC injuries.\(^5^7\) Extrapolating known rates forward to the year 2020, it is estimated, unless there is an unanticipated change in vehicles and people, there will be eight and a half million persons killed each year as a result of (non-war) injuries. Its important to emphasize here that, although partly because of the control of disease by public health measures, it is expected that injuries from MVCs will reach the point where they have become the second commonest cause of disability in the developing world and the third commonest in the whole world.\(^5^8\)

**Prevention**

A recognition of the typical patterns of injury coupled with a logical sequence for the initial assessment and management of trauma patients will contribute to reductions in mortality and morbidity; however, the most significant impact on reducing the worldwide burden of motor vehicle-related trauma will come from injury prevention programs organized at societal and governmental levels.\(^5^9\)

**Seat Belts and Air Bags**

Unquestionably the use of seat belts use has been the most effective tool in saving lives and in the reduction of personal injury when that (inevitable) crash of motor vehicles occurs,\(^6^0\) despite undeniable statistics there are still millions of adults who will not make it their habitual practice to use them, on each and every time they get behind the wheel or sit as a passenger.\(^6^1\), \(^6^2\) The statistics from many countries show that seat belts\(^6^3\) can reduce serious crash-related injuries and deaths by half.\(^6^4\) Although air bags\(^6^5\) supply an
important further protection, especially if they are at the side as well as the front of the car, they are an addition to, and not a substitute for, seat belts. The combination of air bags and seat belts is shown to have supplied the greatest level of protection for adults.66

**Who Is Least Likely To Wear A Seat Belt?**

Unpublished 2010 data from the Centers for Disease Control (CDC), which expertly maintain the US federal government’s health statistics show:

- Adults age 18-34 are less likely to wear seat belts than adults 35 or older.
- Men are 10% less likely to wear seat belts than women.
- Adults who live in rural areas are 10% less likely to wear seat belts (78% use) than adults who live in urban and suburban areas (87% use).

In the various States where they regard enforcement of seat belt laws as relatively unimportant, their (relatively) voluntary use is at 79%, in comparison with 88% where laws are enforced.67

Motor vehicle-related injuries are discussed below in terms of two arbitrary categories, external collision and internal collision. These are explained as:

1. An external collision between the subject and a structure, such as vehicle, tree, road surface, etc.
2. An internal collision in which no external blow is struck, but portions of the subject’s body collide with themselves.

**External Collisions**

When there is a head on collision, sudden cessation of forward movement of the vehicle, those inside it if not secured by belts will continue to travel forwards until they personally collide with the suddenly stationary vehicle. The furthest forward part of the body will be the first to be arrested in this movement, that is feet, ankles and legs; as their movement ceases, the torso continues to flex forward, the as it slows, the head continues forward until it hits something, or has (literally) at times, separated from the
torso. The driver will impact against the wheel, the passenger against the dashboard and the rear seat passengers will fly over the seat in front.

When the vehicle is struck on the side (T-boned as the traffic cops like to say) the persons in it will suffer an impact injury at the side of the chest, torso and pelvis, and be projected away from the side of the impact. Injuries are caused to the ring of the pelvic bones by the compression forces, there is damage to the side of the chest, sudden force on the abdomen increases internal pressure, bursts the diaphragm and tears sold organs such as spleen, kidney and liver. To be thrown from a moving vehicle inevitably is associated with injury, road rash at the very least, more probably there will be major internal injuries to the chest, abdomen and skull, which account for the 20% fatality rate with this type of accident.\textsuperscript{68}

\textit{Deceleration/acceleration injuries}

There are a number of points in the body where a structure is relatively fixed on one side and relatively mobile at the other. When there is a sudden change in speed, an acceleration or deceleration (the usual in crashes), there is a difference in movement either side of these points and a tearing is liable to occur. Examples are the thoracic aorta anchored to the thoracic spine, which decelerates more rapidly than the relatively mobile aortic arch, explaining why the rupture occurs at that point. The same difference in mobility is found at the duodenum, vessels of the kidney, at the junction of the cervical and thoracic spine and even between white and grey matter of the brain. The use of a three-point lap-shoulder seat belt is thought to reduce the risk of death or serious injury for front-seat occupants experiencing these injuries by approximately 45%.\textsuperscript{69}

\textit{Cyclists and Motorcyclists}

Motorcyclists are particularly vulnerable, and for them the fatality rate is 35 times greater than drivers or passengers in cars.\textsuperscript{70} For those who have listened to statistics, since head injury is the usual cause of death after a motorcycle crash, the fatality rate is reduced 30% by the use of helmets.\textsuperscript{71} The terrible facial injuries motorcyclists experience from going over the handlebars are reduced by 70% when helmets with face
masks are worn. Unfortunately helmets do not reduce the 40% incidence of leg fractures incurred in motorcycle accidents.\textsuperscript{72}

Despite the use of helmets and safety drives there has been a steep 55% increase in fatalities due to motorcycle accidents since 2000,\textsuperscript{73} and in the year 2010 they resulted in 4,502 deaths.\textsuperscript{74} The cost of motorcycle crashes is not a mere statistical measurement of corpses, nor a family measure of financial loss and emotional distress. There is a growing public health concern to reduce, if not prevent the severe injuries and the deaths due to motorcycle accidents which are a major financial stressor of emergency services, including field and hospital personnel and a financial burden thrown on the community at large by insurance costs or the cost of caring for the uninsured.\textsuperscript{75}

The financial burden both in terms of outgoing medical costs and loss of productivity as a result of these motorcycle accidents, the deaths caused, the expenses of the care for the injured survivors, has in a single year been estimated at $12 billion.\textsuperscript{76} Each year in the United States there are half a million injuries treated in hospital, and there are 800 deaths as a result of bicycle (pedal cycle) accidents. The most at risk are children between the ages of 5 to 14 years, they present the highest injury rate overall and the highest rate of head injury which is the cause of 75% of the deaths associated with pedal cycles.\textsuperscript{77} The remarkable statistic, incompletely attended to, the use of a helmet will reduce the risk of head injury and brain damage by 88%.\textsuperscript{78}

**Pedestrians**

The pedestrians most at risk are school children, older persons and persons under the influence of alcohol – which pretty much covers the field of who is likely to be on foot.\textsuperscript{79} A report from Toronto described 12% of pedestrian/motor vehicle collisions resulted in major injuries or fatalities; 50% of these fatalities in pedestrian/motor vehicle collisions were over the age of 65 years.\textsuperscript{80}

**Impaired Driving**

In the United States motor vehicle crashes due to alcohol-impaired drivers cause one death every 48 minutes, or 30 people each and every day. Alcohol is behind nearly one-
third (31%) of all traffic-related deaths in the United States, which in 2010 amounted to 10,228 persons killed.\textsuperscript{81} The estimated annual cost of these motor vehicle accidents related to alcohol abuse exceeds $51 billion.\textsuperscript{82} Of the 1,210 traffic deaths among children ages 0 to 14 years in 2010, 211 (17%) involved an alcohol-impaired driver.\textsuperscript{83} Of the 211 child passengers ages 14 and younger who died in alcohol-impaired driving crashes in 2010, over half (131) were riding in the vehicle with the alcohol-impaired driver.\textsuperscript{84}

In 2010, over 1.4 million drivers were arrested for driving under the influence of alcohol or narcotics. These drivers had blood alcohol concentrations of at least 0.08%. This is the illegal blood alcohol concentration level for adult drivers in the United States. U.S. adults drank too much and got behind the wheel about 112 million times in 2010. Alcohol-impaired drivers are involved in about 1 in 3 of crash deaths, resulting in over 10,000 deaths in 2010.\textsuperscript{85} That's one percent of the 112 million self-reported episodes of alcohol-impaired driving among U.S. adults each year.\textsuperscript{86}

Other substances of abuse are implicated in the statistics on MVAs in the US. Drugs such as cocaine and marijuana are a known issue in about 18% of motor vehicle driver deaths, and often they have been used in conjunction with alcohol.\textsuperscript{87,88}

**Young People and Motor Cyclists Are Most at Risk**

At any and every level of blood alcohol concentration (BAC), the risk is greater for young persons than for the old to become involved in a motor vehicle collision.\textsuperscript{89} The statistics for fatal crashes in 2010 show in terms of the BAC a diminishing relationship between age and accident rates. For drivers with BAC levels of 0.08 % or higher, 34% they were in the age group 21 to 24 years of age; the next largest groups were 30% aged 25 to 34, and 25% aged 35 to 44.\textsuperscript{90}

Twenty eight percent of motorcyclists killed in crashes in 2010 had Blood Alcohol Concentrations of 0.08% or greater.\textsuperscript{91} The fatal accidents with motorcyclists are in an older age group, motorcyclists aged 40-44 have the highest percentage of deaths with
BACs of 0.08% or greater (44%), and nearly half of the alcohol-impaired motorcyclists killed each year are age 40 or older.92

**Prior Convictions**

Drivers with a BAC of 0.08% or higher involved in fatal crashes were four times more likely to have a prior conviction for Driving While Intoxicated (DWI) than were drivers with no alcohol in their system (8% and 2%, respectively).93

**Distracted Driving**

Each day in the United States, more than 1,060 people are injured and more than 9 are killed in accidents reported to be associated with distracted driving.94 “Distracted driving” is defined as engaged in another activity that takes attention away from driving. It enormously increases the likelihood of a motor vehicle collision.

There are three main types of distraction:

1. Visual: taking eyes off the road;
2. Manual: taking hands off the wheel;

The police report the most bizarre witnessed activities with equivalent bizarre excuses, but among the commonest distracted driving activities are using a cell phone, texting messages and eating while driving. Seemingly legitimate activities such as the use of a GPS navigation system can be just as dangerously distracting. Texting while driving is especially dangerous because it combines all the named three types of distraction.95 In June 2011, more than 196 billion text messages were sent or received in the US, up nearly 50% from June 2009.96 More than three hundred and eighty thousand persons were killed in the U.S. in 2011 as a result of collisions involving a distracted driver, a slight decrease below the figure for 2010 (416,000 people).

In 2010, nearly one in five crashes (18%) in which someone was injured involved distracted driving. A random self-reporting National Highway Traffic Safety Administration (NHTSA) study found 69% of drivers in the US in the 18-64 age group
admitted that they had used their cell phone while driving; in the same study, 31% of these drivers reported that they had on at least one occasion read or sent text messages or email messages.97 Younger, inexperienced drivers under the age of 20 may be at increased risk; perhaps because their generation is the highest users of cellphones, they are found to have the highest proportion of distraction-related fatal vehicle accidents.98

The CDC study which analyzed the self-reporting data of the 2011 national Youth Risk Behavior Survey, found among high school students in the United States the problem of texting while driving is compounded with drinking while driving and/or riding with someone who has been drinking. The survey found the students who reported these dangerous driving behaviors admitted to at least one incident in the month prior to the survey.99 There was found a statistical relationship in behavior; almost 50% of the U.S. high school students aged 16 years or older were found to text or email while driving, and these same students were nearly 200% more likely to be a passenger in a vehicle whose driver had been drinking and 500% more likely to drink and drive themselves than were students who didn’t text when driving. The students who would frequently text when driving were also more likely to ride with a driver who had been drinking than were the students who sent texts less frequently when they were driving.100

FALLS

Falls are a hazard associated to varying degrees with all occupations. It may happen when simply walking or commonly when using a step-ladder to change a light bulb. Or, less surprisingly, when working in construction on a steel erector 80 feet above the ground. The U.S. Bureau of Labor Statistics, in their 2009 report, recorded data from 605 workers that were killed and an estimated 212,760 workers were seriously injured by falls.101 Out of 4,188 worker fatalities in private industry in calendar year 2011, 738 (17.6%) were in construction. The leading causes of worker deaths on construction sites were falls, 259 out of 738 total deaths in construction (35%), followed by electrocution (9%), struck by object (10%), and caught-in/between (2%).102 Although not surprising,
the highest death rate from fall occurred in the construction industry, but less obviously, the highest number of non-fatal injuries from falls was associated with the health services and the wholesale and retail industries. The occupations particularly at risk of fall injuries were: health care support, building cleaning and maintenance, transportation and material moving, construction and extraction.

Federal regulations and industry consensus standards provide specific measures and performance-based recommendations for fall prevention and protection. However, persistent unsafe practices and low safety culture across many industries define steady fall injury rates year after year. Circumstances associated with fall incidents in the work environment frequently involve slippery, cluttered, or unstable walking/working surfaces, unprotected edges, floor holes and wall openings, unsafely positioned ladders and misused fall protection. Fall injuries constitute a considerable financial burden; workers’ compensation and medical costs associated with occupational fall incidents have been estimated at approximately $70 billion annually in the United States.103

The international public health community has a strong interest in developing strategies to reduce the toll of fall injuries. Many countries are facing the same challenges as the United States on fall injury in the workplace. Successful reduction of fall injury and fatality rates requires continued concerted efforts of regulators and industry leaders, professional associations and labor unions, employers and employees, safety professionals and researchers in enhancing the work environment, implementing new effective fall prevention and protection technologies, and improving the work safety culture through continuous education of the workforce.

The National Institute of Occupational Safety and Health (NIOSH) as the leader in occupational safety research, plays a key role in these complex fall-injury prevention efforts. The objective of one study was to analyze characteristics of chest injuries made by falling from a height. There were 660 persons who fell from various heights up to 70 meters. The falls were accidental in 290 cases and suicides in 370 cases. Thirty six percent had consumed alcohol. The frequency of thoracic injuries increased constantly in falls from heights beyond 3m, so that the rib fractures were present in all falls from heights above 40m. Aortic ruptures were found in 21%, and heart injuries in 16% of all
cases. The frequency of aortic and heart ruptures was not statistically related to the height of the fall. A rupture of the aorta was the most commonly located at the arch (82%). The heart ruptures were the most commonly located on the atrial posterior wall (70%).

**ACTS OF VIOLENCE**

The US National Institute for Occupational Safety and Health (NIOSH) is charged with recommending occupational safety and health standards as well as describing exposures that are safe for various periods of employment, including (but not limited to) the exposures at which no worker will suffer diminished health, functional capacity, or life expectancy as a result of his or her work experience. On average in the US, twenty workers are murdered and 18,000 assaulted while at work each week. These staggering figures should never be considered to be an accepted “cost of doing business” in our society. Neither death nor injury should be the inevitable result of a chosen occupation. No definitive strategy will ever be adequate to prevent violence in all workplaces, but there must be a change in the way work is done in certain settings to minimize the risk to American workers.

NIOSH reviews what is known about fatal and nonfatal violence in the workplace, defines research gaps, and recommends general approaches to prevention of workplace violence. Their document summarizes issues that need to be addressed when dealing with workplace violence in its various settings such as offices, factories, warehouses, hospitals, convenience stores, and taxicabs. Each week in the US, an average of 20 workers are murdered and 18,000 are assaulted while at work or on duty. Violence is a substantial contributor to occupational injury and death.

Risk factors for workplace violence include dealing with the public, the exchange of money, and the delivery of services or goods. Nonfatal assaults result in millions of lost workdays and cost workers millions of dollars in lost wages. Homicide has become the second leading cause of occupational injury death. Workplace violence is clustered in certain occupational settings; for example, taxicab drivers have the highest risk of workplace homicides of any occupational group. The retail trade and service industries...
account for more than half of workplace homicides and 85% of nonfatal workplace assaults. Workers in health care, community services, and retail settings are at increased risk of nonfatal assaults. A report from the major trauma hospital of Damascus, Syria, presented 11 years of experience (888 cases between January 2000 and January 2011) of thoracic trauma admitted to the hospital. This was largely in the era before the civil disturbance. Cases did not include those who died in the emergency department. The leading cause of the trauma was violence (41%) followed by traffic accidents (33%). Violence was the most common cause of chest trauma rather than road traffic accidents in this series. The number of fractured ribs could be used as simple indicator of the severity of trauma. The overall mortality rate was 1.8%; mean length of in-hospital stay was 4.6 days.

BLAST INJURIES

Fortunately still uncommon, Blast Lung Injury (BLI) has, however, gained its own name in the current era of acts of terrorism. There have always been explosions: in coal mining, due to natural gas, propane, as a result of industrial accidents in factories, fuel transportation and storage, grain elevator explosions, etc.; however, the recent acts of terrorists have resulted in such events in larger numbers. "Mass Blast Injury Casualties" is now taught as a specific field of injury in specific circumstances. Between 1991 and 2000, there were 885 terrorist attacks that involved explosions. The 2005 London subway bombings, the 1995 bombing of the Murrah Federal Building in Oklahoma City, the September 11, 2001 Twin Towers in New York City and the Pentagon in Washington DC demonstrated the severity of injuries and deaths that can result from a blast.

Approximately 25,000 US and coalition forces and 100,000 Iraqis were estimated to have been injured or killed by explosions in the Global War on Terrorism as of early 2009. In many parts of the world, undetonated land mines and hand grenades are strewn through abandoned battlefields and regularly cause civilian casualties, even decades after the cease-fire. When a major explosion has occurred it is likely to involve
large numbers of people and to overwhelm the treatment facilities. Careful triage by a highly competent person (ideally, an Intensivist or Anesthesiologist) is required.

**Blast injuries are divided into 4 categories:**

1. Primary: caused solely by the direct effect of blast overpressure on tissue
2. Secondary: caused by flying objects that strike people
3. Tertiary: caused by high-energy explosions; occurs when people fly through the air and strike other objects
4. Miscellaneous or quaternary: encompasses all other injuries caused by explosions, such as burns, crush injuries, and toxic inhalations.

A report from Jerusalem\textsuperscript{115} described the effects of 31 terrorist bomb attacks (TBAs) between 1983 and 2004. There were 29 patients sufficiently distressed with blast lung injury, hypoxic, and had pulmonary infiltrate evidence on X-ray, that they needed to be admitted; within 2 hours of admission (which would not have been long after the time of injury) 76% had to be put on a ventilator, but there was only 1 death (a remarkable success rate that attests to the excellent health care facilities and teams in Jerusalem). The Jerusalem report concluded the following: to expect the early need for mechanical ventilation after this injury.

**INJURIES TO THE CHEST WALL**

**Contusions or hematomas\textsuperscript{116}**

These are essentially the same as “bruising,” and indicate injury, but do not indicate severity of injury. The complete chest, front, back and sides must be examined. The color of the bruise indicates age, bruises go green-yellow with age, the extent of the bruise indicates the extent of bleeding into the skin but tell nothing about the severity of underlying injury. The bruising in a young person indicates an injury of some force, but a simple blow with a fist will cause a bruise without fracture. Extensive bruising in an older person might indicate they are on blood thinners, a clue to other pathology, but do not
presume that is the only explanation for the bruise. The bleeding may come from a damaged structure within the chest, the blood spreads from the chest and spreads into the skin. Fine spots of bleeding, petechiae, may occur in blood dyscrasias, but are associated with traumatic asphyxia when the total chest has been crushed, such as one finds in a patient on whom a tractor has rolled.\textsuperscript{117}

**Subcutaneous emphysema** \textsuperscript{118, 119}
Air escaping from the lung, possibly caused by a fractured rib, may leak into the skin causing swollen pockets of air, like blisters, which crackle on compression. This is a very serious finding and will often be seen on X-ray as black shadows inside the skin. The injury may be higher than the lung, possibly the trachea or even the esophagus.

**Fractures**

**Ribs**\textsuperscript{120}
Fractured ribs are notoriously difficult to see on X-ray in the emergency room, and the smart doctor will never tell a patient, “definitely no fracture.” In general, the problem is not the fracture itself; it’s the effect that the fracture has. Older patients often die from fractured ribs, which result in diminished respiratory movement due to pain, leading to pneumonia and possible death. Some fractures are more significant than others. A fracture of the 12\textsuperscript{th} rib is an indication of kidney damage until proven otherwise. Fractures of the 1\textsuperscript{st} and/or 2\textsuperscript{nd} ribs indicate very severe force has been sustained and there is a high probability of damage to thoracic organs or blood vessels.\textsuperscript{121}

**Flail chest**\textsuperscript{122, 123}
If there are two fractures in the same rib, in particular, if there are two fractures in each of several adjacent ribs, the thorax is no longer the fixed cage, which on expansion will create an internal negative pressure and air drawn into the lungs. Instead there is “paradoxical respiration” – as the chest rises, the injured portion is drawn inwards. The injured person may not immediately be aware of this, pain reduces respiratory movement, but there is very likely to be associated damage with bleeding into the lung at the point of injury; and, respiratory insufficiency is probable. Clinically, it is a finding of
considerable importance and might indicate the need for positive pressure respiration via ventilator. Failing that attention, the patient might unexpectedly descend into total respiratory failure. Surgical stabilization\textsuperscript{124} of the flail chest, particularly the “stove-in” chest\textsuperscript{125} with multiple 2-part fractures, is considered appropriate in a number of the more advanced trauma centers. A stove-in chest, which is not repaired by plate fixation is likely to remain stove-in, effectively collapsed with severe permanent restriction in pulmonary excursion.

\textit{Clavicle}\textsuperscript{126}
Fractures of the clavicle are commonly of little importance besides pain, but they have (rarely) been associated with fatal damage to the underlying blood vessels.

\textit{Sternum}
Fractures of the sternum are similarly relatively unimportant in themselves but significant for the potential of damage to structures deep to the sternum, in particular the arch of the aorta and the heart. For that reason tenderness and/or bruising in the midline with or without a fracture should be considered as a sign of internal injury until proven otherwise.\textsuperscript{127}

\textbf{PULMONARY INJURY AND PLEURAL SPACE INJURY}

\textit{Contusion}\textsuperscript{128}
These have become more common in civilian practice as a result of air bags saving the like of the person in the vehicle but at the same time causing a severe compression of the chest, which is followed by a rapid decompression, collapse of the lungs and rupture of relatively small blood vessels which bleed into the lung spaces. The clinical problem is self-evident, but is imaged on the CT scan as blood within the lungs, and calls for cautions treatment.
The same injury can occur with other forms of trauma, the severity of the trauma related to age, that is, an older person’s chest is a lot less able to withstand a blow before fracturing and collapsing inwards; paradoxically a very young person is more likely to have elastic ribs which do not fracture but neither do they protect the lungs from contusion.

**Laceration**

Open injuries are the most obvious cause of tearing of lung tissue, but it may happen with closed injuries as a result of inward pressure from a fractured rib, or as a result of sudden deceleration, such as a car hitting a tree, when the lungs move forward within the arrested chest, and are torn at their points of attachment.

**Pneumothorax**

Literally, this is a condition of free air within the chest cavity, i.e. the air is no longer contained within the lung. It may be unilateral (dangerous) or bilateral (likely to be fatal). At one time “artificial pneumothorax” was used as a method of putting the lung at rest in the treatment of tuberculosis. Spontaneous pneumothorax is not uncommon, weak areas of the outer lung (blebs) rupture with or without excess respiratory effort, the decision whether to admit and treat depends on the extent to which the lung has collapsed; in many instances no treatment is required, the air is reabsorbed and there are no continuing difficulties. On the other hand the patient may present in severe shock, the chest is tympanitic (drum sound) on percussion and life may be saved by a nurse knowing how to put the largest needle she can find into the upper front of the chest to let out the air that is under pressure – a tension pneumothorax.

Continuing treatment for a pneumothorax requires drainage of the air from the chest until the source of escaping air has been sealed. Classically this was by an underwater drain tube leading from the chest to a bottle of water on the floor, air is blown out via the tube, and bubbles out in the water; an enterprising physician set this up in a plane at 30,000 feet using a Foley catheter and a bottle of Coke; more simply these days a one-way flutter valve (Heimlich) will serve the purpose.
Hemothorax\textsuperscript{132, 133}

In this condition there is blood and air between the pleura and the lung resulting usually from closed trauma. It may be massive or slight. It’s a question of skilled judgment to decide whether tube drainage is required or whether a small amount of blood can be aspirated with a syringe and needle. In general it is not thought wise to leave much blood in the pleural cavity where it is likely to be the cause of adhesions. Flutter valves are generally not an adequate option. Severe continuing bleeding calls for an open surgical exploration of the chest to control the loss of blood which may be from a major vessel or something as seemingly insignificant as an intercostal artery torn with rib fracturing.

Hemopneumothorax\textsuperscript{134, 135}

Both blood and air are found in the pleural cavity. Treatment methods and management decisions are as for hemothorax, and will be based on the cause of leakage of blood and air, the quantity (which will vary from slight to massive), and the availability of skilled help (don’t open a chest if you can’t cope with what you find!). Chest tube insertion is the mainstay of therapy in cases of hemopneumothorax, and is covered later in this course. The following link may be used as an excellent educational tool: http://www.atriummed.com/en/chest_drainage/oasis.asp.

**INJURY TO AIRWAYS**

Blunt tracheobronchial injuries\textsuperscript{136, 137}

Blunt tracheobronchial injuries constitute only a small fraction of admissions to trauma centers, as many patients die before they reach hospital. Tracheobronchial injuries can be difficult to diagnose. Following tracheobronchial transection, peri-bronchial connective tissue may remain intact and allow distal lung ventilation. The presentation of thoracic tracheobronchial injury depends on whether the injury is confined to the mediastinum, or communicates with the pleural spaces. Injuries communicating with the pleural space usually present with hemoptysis, subcutaneous emphysema and a...
pneumothorax that persists despite adequate placement of chest tubes and a continuous air leak. The injury is usually associated with sudden high speed deceleration (car driven into a bridge abutment) the patient is unlikely to live long enough to get to hospital if the trachea is broken across, but if the tear is in the bronchial tree it may be enough to leak air and cause a pneumothorax but not enough to cause symptoms. With a history of an accident of this nature the emergency physician will have that “high index of suspicion” necessary to making the less obvious diagnoses. Even with closed injuries there are likely to be other structures damaged; with open injuries damage to the esophagus should be suspected. Treatment usually requires open thoracotomy and direct repair of the damaged structure.

**Penetrating tracheobronchial injuries**¹³⁸

Up to 80% of penetrating injuries involve the cervical trachea, while 75% of blunt injuries occur within an inch of the division into bronchi at the carina. These injuries always occur in conjunction with other injuries, especially to the great vessels; if there is absent prompt intervention, they are frequently fatal. Respiratory distress, subcutaneous emphysema, pneumothorax, hemoptysis, and mediastinal emphysema are the most common manifestations. Occasionally, complete or near-complete transection results in the "fallen lung" sign on chest radiographs. If possible, perform bronchoscopy on any patient in whom tracheobronchial injury is suggested. Patients with small injuries without appreciable leaks who do not require positive-pressure ventilation can be treated non-operatively; however, most patients require urgent repair. Delay or lack of recognition is common, and subsequent complications of stenosis and obstruction are the rule in missed tracheobronchial injuries.

**Esophageal injuries**¹³⁹

The incidence of injury to the esophagus from external trauma is not known but is certainly less than 1% of injured patients admitted to hospital. The most common cause of esophageal injuries is penetrating trauma from a variety of instruments, including medical activities.¹⁴⁰ Recognition of injury to the esophagus following trauma is difficult in part because of the infrequency of injury, in part because of absence of clinical signs...
in the first (critical) 24 hours, and the presence of multiple other injuries. Delay in
treatment results in the rapid development of intra-thoracic sepsis (mediastinitis), which
has a high fatality rate. Any likelihood of injury calls for prompt investigation, which will
probably include radiography, endoscopy, and thoracoscopy as available and indicated;
the employment of all of these investigative methods can be expected to reveal any
esophageal lesion.

Operative management depends on multiple factors but in general primary repair with
adequate tissue buttressing and drainage is undertaken. Complications after
esophageal repair include such immediate problems as leaks, wound infections,
mediastinitis, empyema, and pneumonia; there are potential long-term problems, for
instance, esophageal stricture.

**Diaphragmatic injuries**

The reported incidence of diaphragmatic rupture is between 0.8% and 1.6% of patients
admitted to hospital with blunt trauma, but there is no particular form of investigation
that will guarantee reliable diagnosis of diaphragmatic rupture. Diaphragmatic rupture
can only be diagnosed on chest X-ray if the stomach or bowel herniates, constricted by
the torn diaphragm (the “collar sign”), or if the nasogastric tube is seen to lie above the
diaphragm. Between a third and two-thirds will be diagnosed on initial chest X-ray, but
this is less reliable if the patient is intubated. The diagnosis of ruptured diaphragm is
frequently missed in the acute phase because of more pressing needs to resuscitate,
such as hypovolemic shock, respiratory insufficiency, visceral injuries or loss of
consciousness.

**Penetrating Diaphragmatic injury**

The diaphragm is frequently injured in penetrating thoraco-abdominal trauma, estimated
at 15% of stab wounds and half of the gunshot wounds (GSWs) that survive to be
brought to the emergency department. Herniation of abdominal contents through the
diaphragm is rarely immediate because in only 15% of the injuries are the perforations
more than an inch in length. Up to 13% of injuries are missed in the stress of
emergency situations; years later the patient may present when visceral herniation

---

141, 142

143
occurs (85% within 3 years), manifesting as decreased cardiopulmonary reserve, obstruction, or frank sepsis. Bowel strangulation and gangrene are associated with a high mortality rate. Because of the relatively small defect, no distinctive signs and symptoms are associated with penetrating diaphragmatic injuries, and diagnosis requires that “high index of suspicion.” They are frequently difficult to diagnose without the laparoscopy, thoracoscopy or laparotomy. In general, acute injuries are approached with laparoscopy or laparotomy because of associated injuries and chronic injuries are approached with thoracoscopy because of dense adhesions that arise between the abdominal contents and the lung.

**CARDIAC INJURY**

**Pericardial tamponade**

Pericardial tamponade is most commonly found after sharp injuries, knives or bullets, but not uncommon after blunt force such as a severe blow to the front of the chest or sudden deceleration car accident (against bridge or tree). The fibrous pericardium is not elastic, and bleeding into the pericardial sac very soon compresses the heart, obstructs passive filling of the atria and will cause death. The patient may or may not be shocked and distressed; heart sounds are muffled, neck veins are dilated and X-rays and ECG are unhelpful. The condition is compared to a tension pneumothorax in that both may need immediate decompression.

The Beck triad (i.e., high venous pressure, low arterial pressure, muffled heart sounds) is documented in only 10-30% of patients who have proven tamponade. The prescribed treatment is by needle aspiration, inserted obliquely under the xiphisternum; the aspirations should be repeated as needed until the bleeding is brought under control. This, unfortunately, is one of the procedures that look easy in diagrams, are practiced and taught in ATLS classes, but in fact are reported by those who have had need to do it, as not successful. Some centers report a false-negative rate of 80% and a false-positive rate of 33%. This procedure is reserved for patients with significant
hemodynamic compromise without another likely etiology. An endoscopic procedure might be more effective.

**Myocardial contusion**

Usually due to a blow to the front of the chest, myocardial contusion occurs commonly but not necessarily at considerable speed. The heart in effect is suspended by the great vessels and has a degree of freedom of movement like a pendulum and can be “whiplashed” between spine and sternum. Contusion of the cardiac muscle is the least of the potential spectrum of injuries, which comprise rupture of the heart muscle, internal (septum) or external, rupture of a valve, and rupture of a coronary artery or vein. All of these may cause a tamponade effect. In the surviving patient, investigation and treatment will follow the usual protocols for acute cardiac care.

**Blunt cardiac injury (BCI)**

Blunt cardiac injury is an embracing term that covers a whole range of injuries varying from simple electrocardiographic (ECG) changes to open rupture of the heart. The incidence is unknown, but clinically significant lesions are rare. There are few reliable clinical signs and symptoms that are specific for BCI. A diagnosis of BCI should be suspected in patients whose mechanism of injury suggests its possibility (e.g. heavy blow to the sternum), and/or who show an abnormally poor cardiovascular response to their injury. No one test or even combination of tests is consistently reliable in detecting cardiac injury. An admission ECG should be performed on all patients where there is suspected BCI; if the patient is hemodynamically unstable, an echocardiogram should be obtained. It is important to recognize that the presence of a sternal fracture does not predict the presence of BCI and, thus, does not necessarily indicate that monitoring should be performed. Neither creatinine phosphokinase with cardiac muscle isoenzyme analysis nor measurement of circulating cardiac troponin T are useful in predicting which patients have, or will have, complications related to BCI. If the ECG shows abnormalities such as arrhythmia, ischemia, heart block, unexplained ST changes, the patient must be admitted for continuous ECG monitoring for at least 24 hours. On the
other hand, if the admission ECG is normal, the risk of having a BCI that requires
treatment is slight.

**Traumatic arrest**\(^{149, 150}\)

The sudden death of an athlete on the football field or the hockey ice is all too well
known. If this follows a blow to the chest it is supposed the electrical mechanism of
conduction failed. In some cases ventricular fibrillation or tachycardia can be
demonstrated thanks to the proliferation of automated external defibrillators (AED)
cardiac monitors;\(^{151}\) it is supporting evidence of a failure of electrical conductivity
(dysrhythmia leading to arrhythmia). Autopsy is likely to be unremarkable. Then there is
always the possibility of other unrecognized conditions such as the “long QT
syndrome.”\(^{152}\)

**Penetrating Cardiac Injuries**\(^{153}\)

Traumatic cardiac penetration is often lethal, recorded death rates of 70-80%.
Ventricular injuries are more common than atrial injuries, and the right side is involved
more often than the left side. The degree of injury, whether there has been cardiac
arrest, go to determining a survival probability to at least reach the emergency
department still while alive, and those who do reach the hospital before cardiac arrest
occurs usually survive. Those patients surviving penetrating injury to the heart without
coronary or valvular injury can be expected to regain normal cardiac function on long-
term follow up.\(^{154}\)

Echocardiography is a rapid, noninvasive, and accurate test for pericardial fluid. It has a
sensitivity of at least 95% and is now incorporated into the “Focused Assessment with
Sonography for Trauma” protocol. In general terms, management is based on the
patient’s hemodynamic status, if facilities are available the patients in extreme or
profoundly unstable condition may benefit from an immediate thoracotomy and
aggressive resuscitation. Absence of an organized cardiac rhythm in patients with gun-
shot wounds (GSWs) from high-caliber missiles, makes death highly probable. For
patients with low-caliber missiles and GSWs, or stab wounds, even though appearing
lifeless on admission, an emergency thoracotomy is appropriate. Stable patients with
cardiac wounds may be diagnosed using a subxiphoid pericardial window. Bleeding must be rapidly controlled using finger occlusion, sutures, or staples. Foreign bodies such as bullets in the left ventricle must be removed.

BLOOD VESSEL INJURIES

Aortic rupture/injury/dissection\textsuperscript{155, 156}

The aorta, largest blood vessel in the body, passes upwards from the heart (ascending aorta), loops back to the spine (arch of the aorta) and turns down to run in front of the spine (descending thoracic), then passes through the diaphragm to be called the abdominal aorta. Any part of the aorta may be injured by a process of degeneration, or by blunt or open (penetrating) trauma. The aorta has an inner lining (endothelium called intima) onto and into which plaques of cholesterol associated lipid substances may form; the fibroelastic wall of the aorta becomes degenerate, loses its elasticity and balloons out as an aneurysm. The aneurysm may rupture internally, stripping its lining as a “dissecting aneurysm”\textsuperscript{157} or it may rupture externally, leaking blood in small or large quantities.

The process of vascular deterioration is associated with ageing, more common with some diseases, particularly common in the diabetic and the smoker. In the ascending aorta, separation of the lining endothelium may block the mouths of the coronary arteries. Abdominal aortic aneurysm\textsuperscript{158} is so commonly seen it is known in emergency departments as “triple A” and it is suggested primary care physicians should equip themselves with simple ultrasound to provide a diagnostic screening of all middle aged patients.

Penetrating injuries of the chest are relatively common in urban societies and, depending to some extent on the character of the society, may be knife or bullet wounds, the former less likely to penetrate the great vessels than the latter. A major bleed is unlikely to survive long enough to reach the emergency room, but a minor injury might. The victim will present with evidence of shock, possibly respiratory distress due
to a hemothorax. Blunt trauma is due usually to a sudden deceleration as in a severe front-end automobile injury. The aorta “whiplashes” and tears from the inside out; sometimes the tear is only the intima and the bleeding then dissects the interior lining away from the outer coat of the aorta – a dissecting aneurysm.\textsuperscript{159} If the outer coats rupture, the accident victim is most unlikely to survive. In fact, even those who do survive because the injury is dissecting and not transecting, the survival rate is very low.

Aortic injuries cause or contribute to 15% of MVA fatalities.\textsuperscript{160} As stated, most patients with blunt aortic injury die before they reach hospital, and the vast majority will have major coexisting thoracic and extra-thoracic injuries. Widening of the mediastinum on an admission chest X-ray is the most common first sign of aortic injury. Aortography is still the “gold standard” diagnostic tool; however, contrast enhanced helical CT scanning can in good hands compare well with aortography. A high index of suspicion may be required in the emergency room in order to diagnose thoracic aortic injury as the initial chest X-ray may be normal and external evidence of injury may be minimal or absent, particularly when the accident occurred without setting off an airbag.

**OTHER INJURIES AND OUTCOMES**

There is no limit to the possibility of injury to other structures if sufficient force is applied. The following section covers trauma assessment scoring systems and additional outcomes related to a traumatic injury. Other traumatic injuries will be covered in another course, however, bear brief mention here in terms of the potential for correlating trauma to other parts of the body, which may impact the pulmonary function and respiration.

**Injury Severity Scoring**\textsuperscript{161}

Characterization of injury severity is crucial to the scientific study of trauma, yet the actual measurement of injury severity began only 50 years ago. In 1969, researchers developed the Abbreviated Injury Scale (AIS) to grade the severity of individual injuries. The AIS is the basis for the Injury Severity Score (ISS), which is the most widely used...
measure of injury severity in patients with trauma. Attempting to summarize the severity of injury in a patient with multiple traumas with a single number is difficult so it is not surprising that many other alternative scoring systems are in use, causing some confusion in comparisons. It is always easy to invent a new system!

**Applications of Trauma Severity Scoring**

The prime practical use of injury severity scoring lies in the ability to predict outcome from trauma, “Will he live?” Obviously patient and family want a prognosis. Use of a trauma severity scoring system and its application support the trauma team when working together to determine a prognosis and treatment plan during a crisis situation.

Injury severity scoring can provide justification to support end-of-life decision-making and resource allocation – no hospital has an infinite number of ICU beds and ventilators. However, predictions in individual patients not which scoring system is employed, must be limited and in general are no better than good clinical judgment.

Decisions for the individual patient should never be based entirely on a statistically derived injury severity score, no matter how convenient it is to be “objective” in decisions. In the field, trauma scoring also is used to rationalize pre-hospital triage decisions, thereby minimizing the time from injury occurrence to definitive management. Similarly, physicians suggest that it can enhance appropriate use of helicopters and timely transfer of severely injured patients to trauma wards. Trauma scoring also is used for quality assurance by allowing evaluation of trauma care both within and between trauma centers. A number always helps to support an argument, and such is widely used with the Glasgow Coma Scale.

**Other Injuries Found in Conjunction with Chest Trauma**

One South African study from the Trauma Unit, Johannesburg Hospital reported the injuries experienced in motor vehicle collisions. In 2001, over 18,000 patients attended the Johannesburg Hospital Trauma Unit and approximately 140 priority-one casualties were treated per month. In that year there were 1715 resuscitations for trauma, 688 for blunt trauma, of which the majority were associated with road traffic
injury. There are characteristic injury patterns, with multisystem injury being the rule rather than the exception.

**Psychological impact of severe injury**

All who work with injured patients should be sensitive to the psychological effects of major injury, as many as 25% of severely injured patients experience significant early psychological reactions after trauma. These reactions can have profoundly adverse effects on quality of life.

**Head injury**

In the western world, the most common cause of death after trauma is severe brain injury; the incidence of death from head injury is approximately 7 per 100,000. In the European Brain Injury Consortium (EBIC) study, 52% of head injuries were related to MVAs. In a prospective study of nearly 3000 head injuries from Scotland, patients were stratified according to the Glasgow Coma Score (GCS) on arrival at hospital: mild injury (GCS 13-15), moderate injury (GCS 9-12) and severe injury (GCS 3-8). Of the initial cohort, 2668 had mild injuries, 133 moderate injuries, and 102 had severe injuries. At follow-up after one year, 1397 were still disabled. Importantly, out of these reported case outcomes there were 1260 (90%) that had been initially assessed as mild injuries.

**Spinal injury**

The United States Major Trauma Outcome Study estimated the incidence of acute spinal-cord injury to be 2.6% of blunt trauma patients.

**Blunt cervical vascular injuries**

In one series from the USA, the incidence of blunt carotid injuries was 1 in every 150 MVAs. Injury to the carotid and vertebral arteries after blunt trauma can lead to severe neurological complications in survivors and a mortality rate of 31%. Blunt cervical vascular injury should be suspected in patients with unexplained weakness close to paralysis (paresis); unequal pupils; cerebrovascular accident or transient
ischemic attack; in the presence of a base of skull fracture, major facial or cervical spinal injury.\textsuperscript{172}

\textbf{Abdominal Injuries}

\textbf{Spleenic injury}

The most commonly injured intra-abdominal organ following blunt trauma is the spleen. Laparotomy should be performed on \textit{hemodynamically unstable} patients with suspected splenic injury. If the patient is \textit{stable}, surgery may not be required as many injured spleens heal without surgical intervention.

Currently, there is acceptance of non-operative management for splenic injury to include adult patients,\textsuperscript{173} taking note of the overwhelming post-splenectomy sepsis in a number of patients who had a splenectomy for trauma; and, recognition that non-operative management of children with ruptured spleens reduces the requirement for blood transfusion and decreases the length of hospital stay. Adjunctive procedures, such as embolization of splenic blood vessels have also been used to reduce the need for operative intervention.\textsuperscript{174}

\textbf{Hepatic injury}

Approximately 85\% of all patients with blunt hepatic trauma are hemodynamically stable, and for them non-operative management shows significantly better outcomes than operative management, expressed in terms of decreased abdominal infections, decreased transfusions, and decreased lengths of hospital stay.\textsuperscript{175} For unstable patients, operative surgery is still the rule, with the “damage control approach” now accepted as the standard of care.\textsuperscript{176}

\textbf{Hollow viscus injury (HVI)}

Individuals subjected to high-speed deceleration in MVAs can experience rupture of intra-abdominal hollow viscera. The mechanism of injury is thought to be compression of closed-loops of bowel by seat-belt restraints. Ecchymosis (bruising) may be seen across the torso under the area covered by the belt, but will not always be found and is therefore more a curiosity than a diagnostic indicator.
The reported incidence of bowel and mesenteric injuries after blunt abdominal trauma is approximately 1.3%. The accuracy of spiral CT is excellent for solid organ injury; however, the same cannot be said for HVI. Accurate and timely recognition can be difficult, and failure to make a timely diagnosis has resulted in significant levels of morbidity and mortality. When three solid organs were injured, HVI was 6.7 times more likely to have occurred than when only one solid organ was injured; the presence of a pancreatic injury plus solid organ injury was associated with HVI in more than a third of patients.

**Pelvic Injuries**

Fractures of the pelvis are a marker of severe injury, as the force required to disrupt the pelvic ring is substantial. All patients sustaining high-energy blunt injury should be assumed to have a pelvic fracture until proven otherwise. Severe bleeding leading to hypovolemic shock is often a feature of severe pelvic fractures. Unstable pelvic fractures can lose blood very rapidly, though the bleeding is internal, and uncertainty about coexistent intra-abdominal injury may cause difficulty in identifying the source of blood loss.

External fixation of an unstable pelvic fracture should be undertaken as early as possible, reducing the disruption of the pelvis, returning the components of the pelvis into stable apposition contributes to hemostasis by reduction of the internal volume of a disrupted pelvis. Pelvic fractures cause problems for physicians “who will not allow themselves to be diverted from the possibility of lethal visceral damage by the presence of broken bones, no matter how obvious.” Examination of the perineum, vagina and rectum is required to rule out open fractures and/or associated urethral injury.

**Extremity Injuries**

The impressive appearance of an extremity injury must not distract practitioners from the priorities of resuscitation. Although polytrauma patients who undergo long bone stabilization within 48 hours of injury have no improvement in survival when compared with those receiving later stabilization, there may be some patients who will have fewer complications. As there is no evidence that early stabilization has any detrimental effect,
the current recommendation is to perform early long bone stabilization in polytrauma patients. They are a great deal easier to nurse when their fractures are stabilized.

TYPES OF THORACIC INJURIES

The following section covers types of thoracic injuries prior to further moving on to the sections that discuss diagnosis and treatment.

Blunt Thoracic Trauma

Every day in the US there are 12 persons out of every million that suffer chest trauma. Motor vehicle collisions are the cause of 75% of these injuries. Of the annual toll of 100,000 deaths in the US due to trauma, 25% are directly due to chest trauma, and chest trauma often has a significant role in the other 75% of deaths.

Thoracic injury

Approximately 85% of all thoracic traumas can be managed without surgical intervention; the mainstays of management are supplemental oxygen, intercostal drainage, good physiotherapy and pain control. The primary survey of the Advanced Trauma Life Support (ATLS) course concentrates on the six immediately life-threatening injuries related to the airway and the chest. An additional six other major thoracic injuries constitute “the deadly dozen” of blunt thoracic trauma, which should be considered during the secondary survey.

Visual Inspection

Although it is essential to perform a complete physical examination, front and back of the completely disrobed patient, this must not be considered the priority. Priority is given to saving life on the well-established ABC routine – Airway, Breathing, Circulation. If the patient can’t breathe it is more important to intubate him than to remove the patient’s shoes and socks!
**Bruising**

Having established priorities, at an appropriate time a complete examination of all surfaces of the body must be made; if there is question of spinal injury (and it is always in question until ruled out) the patient must be log-rolled to examine the back. Bruises will follow direct blows, but not immediately. If the patient is brought to Emergency within a few minutes of injury, they may not be appreciated. The bruise indicates the point of impact, underlying structures should be palpated, such as ribs and sternum, and the position and severity of bruising give a clue to the potential for intra-thoracic damage, but neither their presence nor their absence rule internal trauma in or out – it’s merely suggestive.

**Grazes**

Grazing is more likely to be found after a dragging type of injury, such as will occur if the patient fell from his horse but still had a foot in the stirrup, or was ejected from a moving vehicle. It is also found after bicycle and motor cycle accidents when the patient has been thrown along the road, perhaps still on his bike now horizontal – smart motor cyclists wear “leathers” for this reason – the others ride semi-naked.

**Seat belt signs**\(^{187, 188}\)

Those who object to the mandatory use of seatbelts like to point to the pictures of severe bruising passing diagonally across the chest as a result of arrest of the forward projected body restrained by the oblique shoulder belt, the so-called “seat belt sign.” It may be accompanied by a fracture of the underlying clavicle. They gloss over the fact the patient would have had his face smashed without the belt and quite probably his neck broken.

The statistics are undeniable that deaths from motor vehicle collisions have been greatly reduced by their use. Airplane pilots prefer a 4 point harness, two across the thighs and one over each shoulder – it is required that the airline pilot has these in place on landing and take-off. It is not unlikely the same will one day be required in cars, but we make our progress to safety rather slowly. The patient showing the seat belt sign
must be considered to have a high likelihood of internal organ damage, both thoracic and abdominal.

**DIAGNOSIS**

**Imaging**

**X-ray**

The axiom in the Emergency Department is “Treat the patient, not the X ray.” Attention must be given first and always to the patient's clinical needs. At some time, virtually always, when there has been a chest injury, an X-ray will be taken, probably by the “portable” machine, but necessary care such as intubation or decompression of a tension pneumothorax are clinical decisions that do not need radiographic confirmation. The chest radiograph (CXR) is the initial imaging study of choice in patients with thoracic blunt trauma. A chest radiograph is an important adjunct in the diagnosis of many conditions, including chest wall fractures, pneumothorax, hemothorax, and injuries to the heart and great vessels (e.g., enlarged cardiac silhouette, widened mediastinum). It is now the practice in many hospitals to use digital imaging rather than film, which can make the viewing of the image difficult if the necessary viewing apparatus is not available in the trauma reception room where the injured patient is receiving care.

**CT scanning**

Although the simple antero-posterior portable chest radiograph is better than nothing, there is no question that it is both insufficient and may possibly be misleading in that significant injuries are not displayed. A Computer Assisted Tomography scan (CAT or CT) is enormously more valuable in displaying the evidence of injury, which is commonly missed on simple radiographs. The more recent “helical” version is faster, and can scan the whole body in minutes, another advantage in ensuring less severe and less obvious injuries are not missed when attention is directed to the obvious ones. It is all too easy to miss the ruptured spleen or kidney when a patient presents with a tension pneumothorax. If the helical CT is available in a Level One Trauma Center, the physicians have a great advantage. However, most injured persons do not have the
advantage of being treated in a Level One center, and the emergency physician has then to decide on balance of benefits whether and when it is appropriate for the patient to be wheeled to the Imaging Department for a CT scan – all authorities agree the patient must at the very least be hematologically stable before they are moved.\textsuperscript{193}

In a trauma scenario where there is a question of arterial injury, then arteriography combined with the CT scan is invaluable. This is essentially required when there is a widened mediastinal shadow suggestive of an injury to the arch of the aorta, and many physicians will order it as a routine when there has been the type of impact likely to cause arterial injury, even though there is no clinical or radiologic evidence as yet that it has occurred (forewarned is forearmed).\textsuperscript{194} If there remains suspicion of aortic injury the currently less used method of direct aortography might be required, taking into account that it is considered a better method to show damage of the ascending aorta in particular and in general all of the major thoracic vessels.\textsuperscript{195,196}

\textit{MRI}
This is not generally used for blunt thoracic trauma, except in specific indications, as an example to determine whether the patient has suffered a contusion of his heart or whether the accident has brought on an infarct.\textsuperscript{197}

\textit{Esophagogram}
When injury of the esophagus is suspected, and esophagoscopy has not revealed it, an esophagogram might be indicated, initially using a water-soluble contrast, and only if that has proven negative is barium used as the contrast medium.

\textit{Ultrasound}

\textit{FAST}
Most emergency rooms now have available the relatively inexpensive equipment needed for a rapid assessment conducted by the physician – the expertise of the professional sonographer may not be available at the time needed, and the rapid assessment has become routine. The term FAST is chosen to be indicative of purpose, and has been manipulated out of the words "Focused Assessment Sonography"
Trauma.” The physician will use it in the chest in particular to ensure there is not a hemothorax or hemopericardium, but will also check the abdomen to rule out to the extent possible, bleeding from spleen and kidney.

**Transthoracic Echocardiography (TTE)**

Requires the use of an expert, but is invaluable in assessing the heart for internal damage to valves, or to show disparities in cardiac wall function; it may also assist the expert in evaluating the bizarre ECG changes that are found with cardiac injury.

**Transesophageal echocardiography (TEE)**

Particularly useful in identifying injuries of the thoracic aorta, the study is reliable and relatively easy to perform in the hands of the expert, but only an expert can perform it, and such may not be available in the emergency department.\(^{198, 199, 200}\)

**Endoscopy**

**Esophagoscopy**

Should be performed whenever an injury to the esophagus is suspected; rigid endoscopy is preferred for the cervical esophagus and flexible endoscopy for the intra-thoracic esophagus. The study is performed in conjunction with radiologic esophagogram, both should be performed, not one or the other.

**Bronchoscopy**

When an injury to the tracheobronchial tree is suspected a fiberoptic bronchoscopy should be carried out. If indicated, the endoscopist can under direct vision pass an endotracheal or endobronchial tube to by-pass and seal off a leak until such time as it can be repaired.

**12 lead Electrocardiogram (ECG or EKG)**

This is routinely carried out on all patients with a chest injury, the simpler 6 lead ECG is insufficient. If there is an abnormality such as bundle branch block, not uncommon in older persons, it is enormously helpful to have a previous cardiogram with which it can
be compared. Even if the changes are not new, the treatment might be modified by the
discovery of pre-existing changes, or it is possible the changes found may have been
the cause of the accident, which led to the trauma.

The physician should always be cautious in presuming “no damage” from an early
cardiogram – changes might not be manifest until a later occasion.

**Blood Tests and Transfusion**

*Type and cross-match*

Non-cross-matched blood is sometimes necessary, but is never desirable. For major,
undefined, trauma always have more blood available than the immediate circumstances
suggest the need.

*Complete blood count (CBC)*

Hemoglobin and red cell count are of virtually no benefit in the emergency room
assessment of blood loss, but are necessary markers in following the patient’s progress
over a period of time. White cell count, and in particular platelet count, are also
important.

*Coagulation profile*

To know the parameters of the patient’s coagulation profile is essential, particularly if
any considerable amount of blood is to be given. The profile should include the
following: prothrombin time (PT); activated partial thromboplastin time (PTT); fibrinogen
and degradation products; D-dimer analyses. If after massive transfusion, inexplicable
oozing of blood persists and hemoglobin is falling, the profile should be repeated.

*Arterial blood gas (ABG)*

Monitoring of blood gases is essential to the management of the patient who has any
level of respiratory distress, in particular those who are put on a ventilator.
Electrolytes

All patients who come through Emergency suffering from significant trauma will have a broad screen of blood circulating electrolytes measured as a routine; these will at least include Blood Urea Nitrogen, Creatinine, Calcium, Potassium, Sodium.

Cardiac Enzymes

Serum troponin levels

In all cases of blunt chest trauma there is the potential for cardiac muscle damage, which may or may not be reflected in the ECG. Serum troponin levels are routinely ordered and in general are repeated some hours later because a normal initial level does not mean there is no heart muscle injury. The test is of more use in monitoring progress than in actual diagnosis.

Serum myocardial muscle creatine kinase (CK)

These levels are often ordered, one of those tests performed as a routine, but not of special value in showing whether there has been, or will be, cardiac muscle damage.

Serum lactate levels

Not a cardiac enzyme, but ordered in conjunction with them. Lactate measures cell metabolism in the absence of oxygen (anaerobic glycolysis) and, as such, can be considered to show whether circulating blood oxygenates tissues or whether they are oxygen deprived.

Serial blood lactate measurements are reliable indicators of morbidity and mortality after trauma. Monitoring of blood lactate levels is used as an indicator of improvement. Alternatively, abnormal lactate levels indicate organ failure in trauma victims and help guide teams to prioritize needed interventions and resuscitation efforts.

Pulse oximeter
Routinely applied to all trauma patients, a helpful guide but inadequate in judging the severely injured patient who may need to be intubated.

**TREATMENTS**

**Analgesics**

**Morphine**

The usual method of giving pain relief in the emergency department is by intravenous morphine (called morphia outside the US). It is titrated by giving frequent small doses, and particular caution is required if the patient is in shock. The intravenous route is preferred, in part because of rapid effect and largely because there is uncertainty about absorption if given subcutaneously or by intra-muscular injection.

**Aspirin**

Aspirin is given in the emergency department as a means of reducing blood viscosity in coronary attacks; it is not given for its analgesic effect, and is contraindicated if there is bleeding.

**Regional block**

An intercostal nerve block should be within the competence of every emergency room physician. It is especially of value when the pain of a fractured rib(s) inhibits breathing. The nerve lies with the artery under a kind of lip immediately below the rib, it is usually infiltrated with local anesthetic towards the back of the chest. Potential dangers lie in puncturing the lung with a needle that is inserted too far, or in damaging the intercostal artery, causing bleeding.

**Endotracheal Intubation**

There’s an axiom in the emergency department (lots of axioms there – after all it’s the “life or death” department), this axiom says, “If you think your patient might need to be intubated, he probably should be.” Indications for endotracheal (ET) intubation broadly speaking are when the tissues of the body are inadequately oxygenated; this might be...
the result of airway obstruction by foreign body, saliva, etc., which requires specific clearing. However, more commonly the reasons for intubation are not specific, the patient is lapsing into unconsciousness or some factor not yet defined is causing diminished respiratory effort – and if the patient’s efforts are not mechanically assisted, the patient will die.

Very few patients die from unnecessary intubation, whereas very many die because they did not have an adequate airway. Every trained ER physician knows how to intubate; unfortunately, the opportunity does not often arise and some will hesitate too long. Intubation on the practice dummy (known to all as Resussy Annie) is relatively easy, so is intubation of the unconscious patient, but to anesthetize the conscious patient who suffers respiratory distress requires a level of confidence and skill.

**Crash Endotracheal Intubation**

In the unconscious patient who is not breathing adequately (which is most often the case), the procedure is commonly termed “crash,” which suggests, (and sometimes it is true) at least in the opinion of this author, that little thought or planning is given before doing it. Generally, the unconscious patient can be supported adequately for a time by “Bag-Mask-Ventilation (BVM), which is what the paramedics probably were doing. He should have an adequate oral airway, and be oxygenated as well as possible before this BVM is stopped and the ET tube inserted. In the best emergency departments all is laid out and ready for the crash intubation, the intubator should not start until he is assured all the needed tools are ready and working. No premedication is required.

**Awake Endotracheal Intubation**

If the conscious patient, despite having a compromised airway, is considered unsuitable for an anesthetic, and there are many possibilities to explain that, a skilled anesthetist (rarely an ER physician) might attempt an awake ET intubation. This requires surface anesthesia of the pharynx, larynx and trachea and the passage of the ET tube is greatly assisted if a fiberoptic laryngoscope is available.

**Rapid Sequence Intubation (RSI)**
The fundamental principle is intubation of a non-resisting patient who to that end must not only be unconscious but must also be relaxed. The intubator must be trained, he must have all his medications lined up and ready to go, all his tools lined up and ready to go, and a competent assistant who understands cricoid pressure\textsuperscript{232, 233}, and a planned fail-safe mechanism if the attempt at intubation fails. Typically, the medications chosen are etomidate to induce anesthesia, succinylcholine or rocuronium for short acting paralysis, and as soon as those are effective, cricoid pressure is applied to inhibit reflux from the stomach, the endotracheal tube is passed and the cuff inflated to prevent back flow of air around the ET, its easy disturbance, and to prevent gastric contents entering the lungs.

It is imperative that the correct insertion of the tube be verified (in the trachea and not the esophagus), and some method of securing it to the head is affixed. It is not acceptable at the inquest for the physician to say, “I could see it was in the trachea,” for far too many times it was not. There are various devices to indicate there is carbon dioxide in the air exhaled up the tube, and one of these capnometers must be used and recorded as used. Condensation of air on the inner walls of the tube can occur with intra-esophageal intubation and is not reliable\textsuperscript{234}. The oxygen level on the pulse oximeter may not drop off for some time and this also is not reliable, though if the patient is properly oxygenated it can be expected to rise.

**Mechanical ventilation**\textsuperscript{235, 236, 237, 238, 239, 240}

The tissues of the body require oxygen in order to function – no oxygen is the equivalent of death; healthy, innocent, persons have gone into mine shafts and died because the atmosphere was devoid of oxygen. The patient with an injured chest may be incapable of breathing because of damage to the organs; or the patient may breathe but due, for instance, to pain the patient’s movements are so shallow that breathing is ineffective. Known as *dead space air*, there is a certain amount of air in the lungs and trachea, which has to be expelled for respiration to be efficient. If breathing efforts are shallow, this air is just moved up and down the respiratory tract and there is no effective exchange of gases; carbon dioxide is not expelled and oxygen is not replenished. It is
routine in caring for the injured person to give oxygen, known to all as a necessary commodity. It may be given by simple nasal prongs as a flow of gas to increase the oxygen content of the air naturally inspired. Or it may be given by “bagging” the patient who has a nasal airway; if the patient tolerates a pharyngeal airway then their level of consciousness is dangerously lowered.

Continuous Positive Airway Pressure (CPAP) is given by mask to the conscious patient, and it is given by a relatively simple machine, does not requires a person to “squeeze the bag” as in “bagging” and may be sufficient. One of the most important decisions to be made in caring for the injured person, particularly with chest trauma, is posed by the question, “Are the tissues getting oxygenated?” If there is doubt, if simpler measures do not seem sufficient, the patient should be intubated and started on the mechanical ventilator. The problem can be reduced to one of two possibilities: air is not entering the lungs adequately (failure to ventilate) or gases are not adequately exchanged at the alveolar surfaces (failure to oxygenate). The possible explanations are:

1. Chest cage movement is inadequate to draw air in; the efforts of breathing are too slight to do more than move dead space air.
2. Air is prevented from passing into the lungs;
3. Exchange of gases is blocked at the alveolar surfaces.

It is commonly found that as respiratory insufficiency builds toward the terminal point of respiratory failure, the arterial blood gases drawn to monitor the condition begin to show a PaCO2 of more than 50 mmHg while the oxygen PaO2 falls below 50 mmHg on room air or below 80 mmHg if oxygen is being given. In thoracic trauma, numerous factors are considered in the decision whether to initiate mechanical ventilation, among these are:

- the patient is in shock
- there are multiple injuries
- the patient is comatose
- there is severe blood loss
- there is pre-existing pulmonary diseases such as COPD
• the patient is elderly
• the respiratory rate is above 35 per minute
• there is demonstrated low respiratory power.

The decision cannot be made lightly to initiate mechanical ventilation for once on a ventilator the patient will need to be given care in the ICU; and, the hospital may be limited in the number of ICU beds. Additionally, there is always the risk of “ventilator dependence”, for example, in chronic pulmonary insufficiency where once started on the ventilator the patient cannot safely be weaned off it.

When the decision is made that the patient needs assisted breathing, bag mask ventilation is inadequate and their lungs must be ventilated more effectively, the first step is endotracheal intubation. The ET tube can then be attached to a bag and the patient can be well ventilated with room air, or attached to an oxygen source – this was in effect how patients are cared for during a surgical procedure. It has to be understood that the conscious patient will in general not tolerate an ET tube and must remain sedated.

The mechanical ventilator replaces the human effort of rhythmically pumping air into the lungs, and in its most simple concept is just an electrical pump that turns on and off. Of course, with human ingenuity and advancing understanding of pulmonary physiology and pathology, the ventilator has become quite complex. The respiratory therapist who runs it, usually under the direction of an Intensivist or Anesthesiologist, has taken several years in training and knows how it works, but few emergency room physicians understand it well enough that they do not need skilled advice on how to use it to best effect. In most hospitals oxygen is derived from a piped source and delivered at a wall outlet, the mechanical ventilator is set by the therapist to deliver a certain quantity of air under a certain pressure at a certain frequency.

Chest Tube Drain

*Underwater Chest Tube Drainage*
The use of a chest tube for “closed” drainage has something in common with the endotracheal tube – if you think you might need to use one, you probably do. If it is inserted unnecessarily, but correctly, little harm is caused; if on the other hand it was necessary, but was not inserted, death might ensue. A report from the trauma center of Damascus, Syria, described 888 admitted chest trauma cases between 2000 and 2011; and, of the reported cases there were 41% violence, 33% traffic accidents and 56% were treated by tube drainage whereas only 5.7% required open surgery.249

**Indications**
A chest tube should be inserted whenever there is a substance external to the lungs, which is impeding respiratory function and by its removal would improve function; this includes air, blood, chyle, esophageal and gastric contents and pus. Bilateral chest tubes may be needed in the trauma patient who is in current cardiac arrest on the grounds of a bilateral tension pneumothorax. If the patient is to be transported to another center after a chest injury it is often preferred to insert chest tubes bilaterally as a precaution – all the more so if he is to be air evacuated. Chest tubes are usually left in place after an intrathoracic operation to provide effective drainage. A tube might be inserted to drain an abscess (empyema) if it cannot be evacuated adequately by syringe and needle.

**Diagnostic benefits**
The material coming through in the chest tube assists in diagnosis – air if it is a pneumothorax, air and blood if a hemopneumothorax, milky fluid if chyle from the thoracic duct, undigested food if the esophagus and/or stomach are perforated. The character of blood and its rate of flow are also important in judging whether the bleeding is arterial or venous, and whether the rate of flow is significantly persistent that the chest must be surgically explored.

**Insertion Site**
The pectoralis major muscle forms the anterior wall of the axilla, typically (not invariably) the tube is inserted inferior to the pectoralis major at the anterior axilla, through the highest intercostal space that can easily be palpated, and this is probably the 4th; exact
positioning is rarely important. If the patient is mobile, as he might be after a knife injury but not after a crushing injury, the site selected might be lower and further posterior, which is also preferable for draining fluids.

**Insertion Technique**

At one time every emergency department had a large trocar and cannula (tube with central removable spike) and the emergency physician could rapidly insert this through the chest wall and place a tube in 30 seconds; but typically with progress everything becomes more difficult, and simple techniques are, on the grounds they have been misused, no longer acceptable. Except under the most extreme conditions it must be remembered this is a surgical procedure and should be performed under aseptic conditions.

The skin is infiltrated with local anesthetic, and using a total of about 15 ml, the muscle, periosteum and pleura are infiltrated. Depending on circumstances, the patient might be sedated by intravenous medication. An incision about an inch long, enough to permit the operator's index finger to pass through, is made transversely along the upper margin of the rib. By a combination of blunt digital and blunt instrument dissection, an opening is made through the intercostal muscles, down to the pleura, which may need to be incised. Digital (blind) exploration inside the pleura is performed as required. The tube used is always large bore (they block easily), generally 32-46F, and is poked into place by an instrument. Several inches of the chest tube is inserted. The wound is closed with interrupted sutures in the skin around the tube, firmly sealing the wound; and, sutures may be inserted but not tied where the tube will leave a space when removed. A stay suture is used to tie the tube to the skin.

**Underwater Seal**

There are simple pieces of apparatus and of course expensive complicated ones. A bottle of Coke has served very effectively in some emergency scenarios, such as a combat zone remote to a fully serviced hospital. The important principle to understand whatever the equipment used is to have gravity drainage of fluid, and the potential for
air to bubble out but not to be sucked back in – the reason for the under-fluid drain – it should never be clamped unless about to be removed. In some more complicated apparatus there is low-pressure suction, which may help to expand the lung, but may also keep a leak in the lung open which would otherwise have healed rapidly.

**Complications**

Although tube thoracostomy is often a lifesaving procedure and is relatively straightforward, a review of almost 600 tube thoracostomies revealed a complication rate of 21%. Murphy’s law applies – any and every conceivable complication has happened at some time to some unfortunate person. Mostly they can be avoided by careful, unhurried, aseptic technique. Any organ can be damaged on insertion or by abrasion with an over-stiff, over-long tube; the tube might block and the blockage is not recognized resulting in a tension pneumothorax. Additionally, infection is a risk that may follow its use.

**Drain Removal**

The drain should be removed as soon as it has served its purpose. With the chest fully expanded so the ribs are apart and further air will not enter, extraction is perhaps frightening; however, if performed smoothly it is not usually painful. The sutures should be tied and an occlusive dressing applied.

**Heimlich Valve**

To quote the manufacturers:

“The Heimlich Chest Drain Valve is a specially-designed flutter valve used to replace underwater bottles in chest drainage. Comprised of tubing assembly and sealed transparent housing, the valve establishes a unidirectional flow path for air. This assembly is equipped with tubing connection ends. The Heimlich valve features a blue end to be connected to the patient catheter, and a transparent end to be connected to a vented drainage bag. If necessary, the distal, transparent end can be connected to regulated, intermittent sporadic suction that can be used to remove secretions. The Heimlich Chest Drain Valve is sterile and a single use device.”
The Heimlich valve is excellent for use in a simple pneumothorax such as a burst bleb will occasion; it is less appropriate when there is significant bleeding or other material more solid than air.

**PENETRATING CHEST INJURIES**

**Diagnosis**

Although it is possible to have an occult wound that penetrates the chest wall, it would be rare. The important issue in diagnosis is to be aware of the method of injury to the chest, and the mechanism, in order to provide appropriate treatment.

**Importance of Mechanisms of injury**

They are generally classified in terms of force disseminated through the tissues as: low, medium, or high velocity. Low velocity injuries penetrate the tissues in the pathway of the inserted object, such as a knife or a spike, but do not affect adjacent tissues. Medium velocity injuries such as wounds caused by bullets from handguns (revolvers, pistols); there is some distribution of force to the immediate surroundings, but not a great deal. High velocity injuries such as a military rifle bullet; there is extensive damage to the surrounding tissues due to violent vibration caused by the dissemination of kinetic energy, resulting in cavitation of adjacent tissues.

The force blows sideways the tissues through which the missile passes, a cavity is created which then incompletely subsides. Blast fragments from grenades and other types of bombs may travel at even higher speed than bullets, with greater associated kinetic energy and greater damage, in part due to their size and shape and in part due to dissemination of energy.
Damage Control

The essence of treatment consists of preventing the situation from becoming worse, followed by whatever is necessary to improve it.

First Responder

Immediate care given by first responders follows the usual ABC pattern, establishing a satisfactory airway so the patient can breathe, and starting treatments to prevent or reverse shock. The treatment rendered depends on the skills available.

Crash intubation might be called for, but should not be attempted unless the attendant (paramedic or doctor) is competent and adequately equipped. Oxygen is given by bag ventilation and mask (BVM). A tension pneumothorax can be diagnosed readily if of sufficient magnitude to require urgent treatment, and very little skill is required – the largest bore needle available is pushed through the uppermost intercostal space in the mid-clavicular line, and left in place to allow continuing decompression and escape of air. One or more intravenous infusions are started with a large bore needle, usually normal saline is what’s available, and if there’s any evidence of shock the IV is run “open” and possibly manually compressed. Wounds are dressed; a sucking wound indicating pleural perforation should be dressed in such a way that air can still escape and treatment does not cause a tension pneumothorax. First aid in the field is limited in both skills and equipment. To the extent possible the treatment is given “on the run.” That is, inside the moving ambulance or helicopter, which is transporting the injured person to a competent trauma center. The old idea of the “nearest hospital” has been abandoned since the nearest hospital too often has proven incompetent in dealing with casualties. The injured person should be transported to the nearest facility equipped and certified to deal with their injuries.

The Injury

It should be anticipated that more than one structure has been damaged, and the surgeon should not be satisfied with a single major explanation for minor problems, which may later become of major importance. Clearly the tissues at risk depend on the
nature of the injury; a stab wound may damage any structure in the chest but is not likely to damage the neck. In contrast, a grenade wound or Improvised Explosive Device (IED) might well have thrown the victim and caused a fractured neck as well as a sucking chest wound and ruptured diaphragm. In one report of 755 patients with thoracic trauma the distribution of pathology was as follows: \(^{270}\)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemothorax</td>
<td>190</td>
</tr>
<tr>
<td>Hemopneumothorax</td>
<td>184</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>144</td>
</tr>
<tr>
<td>Diaphragmatic rupture</td>
<td>121</td>
</tr>
<tr>
<td>Open hemopneumothorax</td>
<td>95</td>
</tr>
<tr>
<td>Pulmonary contusion</td>
<td>50</td>
</tr>
<tr>
<td>Open pneumothorax</td>
<td>24</td>
</tr>
<tr>
<td>Rib fracture</td>
<td>29</td>
</tr>
<tr>
<td>Fewer than 2 fractures</td>
<td>16</td>
</tr>
<tr>
<td>More than 2 fractures</td>
<td>13</td>
</tr>
<tr>
<td>Subcutaneous emphysema</td>
<td>14</td>
</tr>
<tr>
<td>Bilateral pneumothorax</td>
<td>9</td>
</tr>
<tr>
<td>Open bilateral hemopneumothorax</td>
<td>13</td>
</tr>
<tr>
<td>Pneumomediastinum</td>
<td>6</td>
</tr>
<tr>
<td>Thoracic wall lacerations</td>
<td></td>
</tr>
<tr>
<td>Bilateral hemopneumothorax</td>
<td>3</td>
</tr>
<tr>
<td>Open bilateral pneumothorax</td>
<td>3</td>
</tr>
<tr>
<td>Sternal fracture</td>
<td>3</td>
</tr>
<tr>
<td>Bilateral diaphragmatic rupture</td>
<td>2</td>
</tr>
</tbody>
</table>

Clearly this set of injuries did not comprise heart injuries; it is instructive but not generally representative of all clinical situations. Some communities will be heavy on knife wounds, and others on bullet wounds or traffic crush injuries. The military will experience all the injuries of civilian life as well as high velocity Gun Shot Wound (GSW) injuries, and, now in present war circumstances, blast injuries from IEDs.

**SURGERY**

The following section highlights surgical and non-surgical interventions during a chest injury scenario. Today, emergency resuscitation involves a variety of approaches.
**Immediate Thoracotomy**
Patients who arrive in cardiac arrest or who arrest shortly after arrival may be candidates for emergency resuscitative thoracotomy. The use of emergency resuscitative thoracotomy has been reported to result in survival rates of 9% to 57% for patients with penetrating cardiac injuries, and survival rates of 0% to 66% for patients with non-cardiac thoracic injuries, but overall survival rates are approximately 8%.

**Non-surgical treatment**
The proportion of patients with Penetrating Chest Trauma (PCT) who can be treated without operation has been reported to vary from 29% to 94%. The main modalities of non-surgical treatment of chest wall injuries include a combination of pain control, aggressive pulmonary and physical therapy, selective use of intubation and ventilation, and close observation for respiratory decompensation.

**Acute Indications for Thoracotomy**
- Cardiac tamponade
- Acute hemodynamic deterioration/cardiac arrest in the trauma center
- Penetrating truncal trauma (resuscitative thoracotomy)
- Vascular injury at the thoracic outlet
- Loss of chest wall substance (traumatic thoracotomy)
- Massive air leak
- Endoscopic or radiographic evidence of significant tracheal or bronchial injury
- Endoscopic or radiographic evidence of esophageal injury
- Radiographic evidence of great vessel injury
- Mediastinal passage of a penetrating object
- Significant missile embolism to the heart or pulmonary artery
- Transcardiac placement of an inferior vena caval shunt for hepatic vascular wounds
Indication for acute thoracostomy is often based on chest tube output. Immediate evacuation of 1500 mL of blood is a sufficient indication; however, the trend in output is more important. If bleeding persists with a steady trend of more than 250 mL/h, thoracotomy is probably indicated.

**Chronic Indications for Thoracotomy**

- Nonevacuated clotted hemothorax
- Chronic traumatic diaphragmatic hernia
- Traumatic cardiac septal or valvular lesion
- Chronic traumatic thoracic aortic pseudoaneurysm
- Nonclosing thoracic duct fistula
- Chronic (or neglected) posttraumatic empyema
- Infected intrapulmonary hematoma (e.g., traumatic lung abscess)
- Missed tracheal or bronchial injury
- Tracheoesophageal fistula
- Innominate artery/tracheal fistula
- Traumatic arterial/venous fistula

**Thoracoscopy**

The role of video-assisted thoracoscopic surgery in the management of penetrating chest trauma is expanding rapidly. Initially promoted for the management of retained hemothoraces and the diagnosis of diaphragmatic injury, trauma and thoracic surgeons are now using thoracoscopy for treatment of chest wall bleeding, diagnosis of transmediastinal injuries, pericardial window, and persistent pneumothoraces. Hemodynamic instability is the major contraindication to video-assisted thoracoscopic surgery.
PRIMARY BLAST INJURIES

Unique patterns of injury are found in all blast types. The lungs, bowel, and middle ear are most susceptible to primary blast injuries (PBIs).

Pulmonary barotrauma
The most commonly fatal PBI, may include:

- Pulmonary contusion
- Systemic air embolism, which most commonly occlude blood vessels in the brain or spinal cord
- Injuries such as thrombosis, lipoxygenation, and DIC
- Impaired pulmonary performance lasting hours to days
- ARDS may be a result of direct lung injury or of shock from other body injuries

Lab tests
These are essential for accurate diagnosis in the mass-casualty situation, but consider:

1. Do not overwhelm the laboratory with screening or protocol laboratory tests of little clinical benefit.
2. Most patients injured by significant explosions should have a screening urinalysis.
3. If the explosion occurred in an enclosed space or was accompanied by fire, test for carboxyhemoglobin (HbCO) and electrolytes to assess acid/base status. Pulse oximetry readings may be misleading in cases of CO poisoning.
4. Victims of major trauma should have baseline hemoglobin determinations, crossmatching for potential blood transfusion, and screening for disseminated intravascular coagulation (DIC).

Chest radiography
Chest radiography is required with a history of exposure to high overpressure, tympanic membrane rupture, respiratory symptoms, abnormal findings on chest auscultation and visible external signs of thoracic trauma. Concurrently, if there is significant abdominal pain present, consider an immediate abdominal radiographic series (flat and upright films) or abdominal CT to detect pneumoperitoneum from enteric rupture. Intestinal barotrauma is more common with underwater than air blast injuries.

Focused Abdominal Sonography for Trauma (FAST) is a potentially useful tool for rapidly screening patients, especially in the setting of multiple seriously injured victims. A positive FAST examination in an unstable patient is an indication for surgical exploration of the abdomen in the operating room. A negative FAST examination is unreliable in the setting of penetrating trauma to the abdomen, flank, buttocks, or back, and it should be followed up with CT examination of the abdomen and pelvis.

**PROGNOSIS AND RECOVERY**

Mortality rates vary widely reflecting varied severity of chest and other injuries; the outcome and prognosis for the great majority of patients with blunt chest trauma are excellent.\textsuperscript{277} Most (more than 80\%) require either no invasive therapy or, at most, a tube thoracostomy for relief of their injuries.

The most important determinant of outcome is the presence or absence of significant associated injuries of (in particular) the central nervous system, and also the abdomen and pelvis. Some injuries, such as cardiac chamber rupture, thoracic aortic rupture, injuries of the intrathoracic inferior and superior vena cava, and delayed recognition of esophageal rupture, are associated with high morbidity and mortality rates. In one series of patients\textsuperscript{278} with chest and other injuries, the overall mortality was 5.3\%; the commonest causes of death were respiratory sepsis, severe head injury, and exsanguination. The mortality was 37.5\% for patients older than 60 years, with
respiratory failure. In another series, there was a 16% mortality in patients with isolated pulmonary contusion, and 42% when associated with flail chest.

The outcomes of treating patients with penetrating chest trauma are directly related to the extent of patients’ injuries and the timeliness of initiation of treatments. Patients arriving in a stable condition may expect full recovery, but patients presenting with lesser levels of stability have diminishing probabilities of survival. The ER staff should not attempt to resuscitate, let alone definitively treat, patients presenting with no vital signs or with obviously non-survivable injuries (e.g. massive cardiac destruction).

Reporting from a single center in 2010, patients who died had a significantly lower systolic blood pressure (42 +/- 36 mmHg) compared with those who survived (83 +/- 27 mmHg, p< 0.001).²⁷⁹

**PEDIATRIC CHEST INJURIES²⁸⁰**

Children are not just “little adults”!

In the US, trauma is the leading cause of death in patients younger than 18 years, amounting to more than 5,000 deaths each year. Of these deaths, although thoracic trauma accounts for only 5-12% of admissions to a trauma center, it is second to head injury as the most common cause of death. Multisystem involvement is reported in more than 50% of children with thoracic trauma and carries a much worse prognosis – deaths from isolated thoracic trauma are 5% but climbs to as much as 35% when associated with concomitant abdominal and head injuries.

Childhood thoracic injury is most appropriately defined as multisystem injury. Analysis of the National Pediatric Trauma Registry reveals that blunt trauma accounts for approximately 85% of chest injuries serious enough to warrant treatment.²⁸¹ Almost three fourths of these chest injuries were caused by motor vehicle accidents, with the remainder caused by to motorcycle-related trauma, falls, and bicycle accidents.
Penetrating trauma comprises 15% of chest injuries in children, usually due to gunshot and knife wounds.

**Blunt chest trauma**
This is usually the result of a motor vehicle accident; often the child is a pedestrian. Because of its frequent association with motor vehicle accidents, chest trauma usually occurs in association with injuries to other major systems, such as the head and the abdomen. Eighty-six per cent of patients with thoracic injuries had an injury to one or more other body regions, which brings to attention the high force involved in most pediatric chest trauma cases.

**Mortality**
Mortality in children with chest trauma is high, although death is not always related directly to the chest injury. Regardless of the mechanism of thoracic trauma, 15% of children do not survive. According to the analysis of the National Pediatric Trauma Registry, almost half of the deaths in those with blunt injury were due to associated neurological injury, compared with children who had penetrating chest trauma, in whom all fatalities are due to the chest injury itself. Death usually occurs soon after the injury in a child, whereas an adult with comparable injuries tends to survive longer.

**How children are different**
A major difference between adults and children is the compliance of the chest wall, due to the greater elasticity of the ribs. This allows greater deformation of the chest wall before the ribs fracture. Thus major internal injuries may occur without any external chest wall injury. Children have a greater cardiopulmonary reserve, and so compensatory mechanisms may mask hypovolemia and respiratory distress. A drop in blood pressure in the pediatric population is a very late sign, signifying imminent death. The mobility of the mediastinum decreases the risk of major airway and vessel injury. However, ventilatory and cardiovascular compromise may occur rapidly due to the mediastinal shift. A common response of injury in children is aerophagia, which is often
associated with a reflex ileus. This can lead to acute gastric dilatation, which may further compromise respiratory function.

**SUMMARY**

All whose lives engage them in the fields of health care will have an interest in the prevention of accidents, and, for most, their prime activities lie in the treatment of the accident victims. Injuries to the chest although not the leading cause of death are major factors in death and disability caused by trauma. Appropriate care given at the time of need goes a long way in reducing the number of preventable deaths, but appropriate care mandates appropriate knowledge and the courage to employ it.

Improvements in diagnostic techniques by tools such as the spiral CT scanner and the thoracoscope have done much to expand our diagnostic capabilities, but there is no substitute for clinical acumen, the ability to make a diagnosis based on the simplest of clinical assessments with hands, eyes and ears, and the emotional strength to act promptly and appropriately under duress. This article described the function of the respiratory system, the damage caused by open and closed trauma to the chest wall and the visceral contents of the chest, and the *take home message* is to understand the ABCs and to act according to recommended standards of care and when needed in emergency situations.
REFERENCES

5. http://www.youtube.com/watch?v=9bfI3Jtfng8&list=SPE69608EC343F5691&index=1
8. http://www.youtube.com/watch?v=S9OWa8ot75o&list=PL2190820B24F1B804
10. http://oac.med.jhmi.edu/res_phys/Encyclopedia/PleuralPressure/PleuralPressure.HTML
11. http://oac.med.jhmi.edu/res_phys/Encyclopedia/AlveolarPressure/AlveolarPressure.HTML
12. http://hyperphysics.phy-astr.gsu.edu/hbase/ptens2.html
15. http://library.med.utah.edu/WebPath/LUNGHTML/LUNGIDX.html
22. http://www.nhlbi.nih.gov/health/health-topics/topics/asthma/
24. https://www.google.ca/search?q=pulse+oximeter&tbm=isch&tbo=u&source=univ&sa=X&ei=UC_tUZTGA5DdqwGM5oDYBA&sqi=2&ved=0CFgQsAQ&biw=1920&bih=947
27. https://www.google.ca/search?q=atelectasis+images&tbm=isch&tbo=u&source=un
http://www.nhlbi.nih.gov/health/health-topics/topics/atl/

https://www.google.ca/search?q=atelectasis+images&tbm=isch&tbo=u&source=univ&sa=X&ei=MzDtUebIIYjCrQGdw4H4Dw&sqi=2&ved=0CCwQsAQ&biw=1920&bih=947

http://www.lung.ca/diseases-maladies/a-z/embolus-embolie/index_e.php
http://www.youtube.com/watch?v=FVhgJvJ8hw
http://www.youtube.com/watch?v=p4Tod9S1iB0
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2776366/
http://www.rescuediver.org/med/ag.htm
http://www.patient.co.uk/doctor/Fat-Embolism.htm
http://ccn.aacnjournals.org/content/24/4/54

https://www.google.ca/search?hl=en&gs_rn=20&gs_ri=psy-ab&tbm=isch&source=qq&sa=N&tab=wi&ei=MzDtUebIIYjCrQGdw4H4Dw&sqi=2&ved=0CCwQsAQ&biw=1920&bih=947

https://www.google.ca/search?hl=en&gs_rn=20&gs_ri=psy-ab&tbm=isch&source=qq&sa=N&tab=wi&ei=MzDtUebIIYjCrQGdw4H4Dw&sqi=2&ved=0CCwQsAQ&biw=1920&bih=947


http://deepblue.lib.umich.edu/bitstream/handle/2027.42/67129/10.1177_10901981401100205.pdf?sequence=2


88 van der Spuy JW. Trauma, alcohol and other substances. S Afr Med J 2000; 90(3): 244-46


101 http://www.cdc.gov/niosh/topics/falls/
102 http://www.cdc.gov/niosh/topics/falls/


105 http://www.cdc.gov/niosh/docs/96-100/
106 www.ajol.info/index.php/cme/article/download/43996/27512
107 http://www.cdc.gov/NIOSH/


http://emedicine.medscape.com/article/822587-overview#a0101

R9N9dIdXg&pq=car+crash+aortic+injury&cp=13&gs_id=1g&xhr=t&q=dissecting+a
neurysm&bav=on.2,or.r_qf.&biw=1920&bih=947&um=1&ie=UTF-8&tbnid=lsch&source=og&sa=N&tab=wi&ei=DVrtUYiJCuP0yQHv-oGACw
http://www.webmd.com/heart-disease/heart-disease-aortic-aneurysm
http://jcp.bmj.com/content/11/1/36.full.pdf
http://www.trauma.org/archive/thoracic/CHESTaorta.html
http://emedicine.medscape.com/article/434076-overview#showall
http://www.merriam-webster.com/dictionary/triage
Davis KA, Fabian TC, Croce MA, Gavant ML, Flick PA, Minard G, et al. Improved success in nonoperative management of blunt splenic injuries: embolization of

nursece4less.com nursece4less.com nursece4less.com nursece4less.com nursece4less.com nursece4less.com nursece4less.com

74


185 http://emedicine.medscape.com/article/428723-overview#a30

186 www.ajol.info/index.php/cme/article/download/43996/27512

187 http://regionstraumapro.com/post/663723636


Chirillo F, Totis O, Cavarzerani A, et al. Usefulness of transthoracic and transoesophageal echocardiography in recognition and management of...


http://www.guideline.gov/content.aspx?id=35259

http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2966563/

http://www.nysora.com/peripheral_nerve_blocks/nerve_stimulator_techniques/308-8-intercostal-nerve-block.html

https://www.google.ca/search?q=intercostal+nerve+block&tbm=isch&tbo=u&source=univ&sa=X&ei=26vlUYC XKsSEygH8xIC4DQ&ved=0CDcQsAQ&biw=1920&bih=947


Sagarin MJ, Barton ED, Chng YM, et al. Airway management by US and Canadian emergency medicine residents: a multicenter analysis of more than 6,000


235 http://www.ccmtutorials.com/rs/mv/

236 http://emedicine.medscape.com/article/304068-overview

237 http://www.youtube.com/watch?v=V8VIw0fk4X0


239 https://www.google.ca/search?q=mechanical+ventilation&tbm=isch&tbo=u&source=univ&sa=X&ei=WtLlUejEj3EYHWygGZjoHIDQ&sqi=2&ved=0CEoQsAQ&biw=1920&bih=947

240 http://www.nhlbi.nih.gov/health/health-topics/topics/vent/

241 http://www.nursingtimes.net/making-sense-of-arterial-blood-gases/200822.article


243 http://www.youtube.com/watch?v=tSXQ7GR35E4

244 http://www.icufaqs.org/ChestTubes.doc
http://www.trauma.org/archive/thoracic/CHESTdrain.html
http://dynamicnursingeducation.com/class.php?class_id=33


https://www.google.ca/search?q=heimlich+valve+chest+tube&tbm=isch&tbo=u&source=univ&sa=X&ei=r_zmUdi1CqiPjyAGOp4DYDA&ved=0CCwQsAQ&biw=1920&bih=947
http://www.slideshare.net/posadashazel/treating-penetrating-chest-trauma
http://ats.ctsnetjournals.org/cgi/content/full/72/2/342


http://emedicine.medscape.com/article/425698-overview#showall
http://www.cts.usc.edu/lpg-thoracoscopy-thethoracoscopyprocedure.html

http://emedicine.medscape.com/article/1970013-overview


http://www.aic.cuhk.edu.hk/web8/chest_injuries.htm
