TRAUMA SERIES:
POLYTRAUMA

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ABSTRACT
The field of medicine is rapidly advancing, which means that we can save many people who once would have been lost to serious injury. However, these advances have created an influx of polytraumatic patients—patients with two or more acutely serious injuries, at least one of which is life threatening. Medical staff needs to be prepared to meet the unique needs of these patients, from the field to the emergency room and in both acute and post-acute care situations. Additionally, it is absolutely vital that medical professionals understand the psychological needs of polytraumatic patients so they can help them achieve healing of both body and mind.

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Credit Designation
This educational activity is credited for 16 hours. Nurses may only claim credit commensurate with the credit awarded for completion of this course activity.

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**Statement of Need**

Initial stabilization of the polytrauma patient requires well-prepared teams to ensure life is saved. Patients with polytrauma show a high prevalence of post trauma biopsychosocial symptoms. Nurses are essential members of the trauma and critical care health teams. Educating nurses to provide competent early trauma and follow-up care is an essential requirement that significantly reduces morbidity/mortality, and improves quality of life, for polytrauma victims.

**Course Purpose**

This course will provide advanced learning for nurses interested in the management of the individual with polytrauma.

**Learning Objectives**

1. Define polytrauma.
2. Explain the increased incidence of polytrauma in recent years.
3. Describe the influence of modern warfare on polytrauma incidence.
4. Understand common causes of civilian polytrauma.
5. Recognize the role of TBI in polytraumatic patients.
6. Identify major injuries commonly seen in polytraumatic patients.
7. Explain the recommended staffing per polytraumatic patient.
8. Perform an ABCDE assessment on a polytraumatic patient.
9. Explain environmental control requirements for an emergent polytraumatic patient.
10. Identify the elements of a trauma series x-ray.
11. Describe the role of ECMO in a polytraumatic emergency.
12. Understand the elements of a secondary survey.
13. Complete a comprehensive patient history on a polytraumatic patient.
15. Describe the common psychological effects of polytraumatic injury.
16. Identify community resources for polytraumatic patients dealing with psychological effects.
17. Explain long-term treatment options for polytraumatic patients.
18. List the U.S. Polytrauma Specialization Centers
19. Describe the differences between private specialization centers and DVA specialization centers
20. Recognize resources for civilian outpatient care and support.

Target Audience
Advanced Practice Registered Nurses, Registered Nurses, Licensed Practical Nurses, and Medical Assistants

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Jassin M. Jouria, MD has no disclosures
William S. Cook, PhD has no disclosures
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INTRODUCTION

Due to advances in the field of medicine, many individuals who would have once been lost to serious injury can now be saved. As a result, the number of polytrauma patients — those with two or more acutely serious injuries, one of which is life threatening — has increased. Polytrauma is complex and requires medical personnel with advanced knowledge of emergency treatment and management (1). Medical personnel must be prepared to meet the unique needs of these patients, from the field to the emergency room and in both acute and post-acute care situations. Additionally, it is absolutely vital that medical professionals understand the psychological needs of polytraumatic patients so they can help them achieve healing of both body and mind.

Polytrauma occurs as the result of accidents or during military combat. In either instance, the treatment must be tailored to meet the specific needs of the patient. In combat situations, polytrauma is caused primarily by blast related trauma, while civilian trauma can be caused by a number of incidents including motor vehicle accidents, bicycle accidents, firearms, industrial accidents and any other accidents that have the potential to cause severe injuries. Polytrauma is complex and requires a diverse range of services to best meet the needs of the individual patient. Polytrauma care providers must be able to provide initial care that is focused on patient stabilization, while also working to address any secondary issues that are caused by the trauma (2).

DEFINITION AND INCIDENCE

Polytrauma involves multiple injuries, which are typically complex. At least one of the injuries is life-threatening and requires immediate care. Polytrauma often has long lasting effects on the patient and can result in physical, cognitive, psychological or psychosocial impairments and disability. Polytrauma differs
from general multiple injuries in a patient, as these are often not severe or life threatening. Polytrauma is also different from a single, severe, life threatening injury (3). Ultimately, what distinguishes polytrauma from other injuries is that it is specifically defined as multiple, complex injuries of which at least one is life threatening.

Polytrauma is primarily caused by critical accidents and is especially prominent in the military population as a result of combat. The following is a list of the common causes of polytrauma:

Type of Accident:
- Road traffic accidents
- Industrial accidents
- Sport accidents
- Accidents in leisure time
- Accidents in the home
- Violent crimes
- Burials
- Suicide attempts
- Catastrophes
- Effects of war
- Accidents caused by internal conditions (e.g. heart attack)

Mechanism of accident:
- Deceleration trauma
- Fall trauma
- Trauma resulting from being run over
- Crush trauma
- Avulsion trauma
- Penetrating injury
• Explosion injury
• Thermal injury
• Chemical injury
• Radiation injury (4)

Polytrauma is the leading cause of death globally. The death rate is highest in individuals under the age of 44, with trauma being the leading cause of death in individuals under the age of 35. In the United States, blunt trauma caused by motor vehicle accidents and falls is the primary cause of death in polytrauma victims. In combat situations, polytrauma is usually the result of explosive devices and contact with flying shrapnel or gunshots. Polytrauma is also the leading cause of disability in individuals between the ages of 15 – 24 (5). According to the World Health Organization (WHO), the following incidents accounted for the majority of non-combat polytrauma:

• Road Traffic Accidents – 24.3 million
• Falls – 37.3 million
• Violence – 17.2 million
• Fires – 10.9 million (6)

In the civilian population, polytrauma is very complex and impacts patients differently depending on the type of accident and the body parts affected. In combat situations, explosive devices and flying shrapnel often cause polytrauma. As a result, there are some commonalities amongst patients. In these instances polytrauma is typically characterized by: traumatic brain injury, significant body wounds, infections, severed limbs or spinal cord damage, bone fractures, vision and hearing loss, and nerve damage (7). Many military patients also experience long-term emotional and behavioral damage as a result of the complexity of the injuries (8). While the damage is often extensive, more military personnel survive these incidents than previously due to advanced medical care and a better understanding of polytrauma care and management (9).
Due to the severity of injuries with polytrauma, immediate emergency care is crucial. In many instances, the patient has a high risk of mortality as a result of the injuries sustained (9). However, with immediate emergency care and treatment, the patient’s chance of survival increases. Most deaths occur within the first hour after an injury (10). If treatment begins during this crucial hour, there is a chance that the patient may survive, assuming the life-threatening condition is treatable. In some instances, there is nothing that can be done medically to treat the condition (9). The next crucial stage occurs from 1 – 4 hours after the accident. This phase is often referred to as the “golden hour” and it is often when most of the emergency treatment occurs (11). During this stage, the most common cause of death is from hypovolemic shock (9). Once a patient passes through this stage and is stabilized, the individual’s chance of survival increases greatly. However, the patient is still at risk of developing complications or succumbing to multiple organ failures. This can occur within the first few weeks of recovery (8).

Due to the nature of polytrauma and the risks involved throughout the course of treatment, providers must take a long-term approach to treatment and care. Initial treatment involves emergency treatment and management and occurs within the first few hours of the accident (12). This stage is used to treat and manage any of the immediate, life threatening conditions that are present. The second stage of treatment, which is called acute care, involves care during the first few weeks of recovery. During this time, the patient is hospitalized and other injuries are treated (1). This period is also used to provide further treatment for the critical injuries and to ensure that the patient does not develop further complications (12). The final stage of care extends beyond the initial few weeks, and may continue throughout the duration of the patient’s life. Care during this stage focuses on long-term injuries and disabilities such as traumatic brain injury or musculoskeletal injuries that require extensive therapy and recovery time (13). In all stages of treatment and care, the treatment plan is developed to meet the specific needs of the patient.
COMMON CAUSES

Polytrauma is caused by extreme accidents and military combat. Typically, the causes of polytrauma are divided into two categories: civilian and military. Civilian polytrauma is often the result of extreme accidents such as car accidents, gunshot wounds, industrial accidents, violent crimes, and suicide attempts. Due to the complexity of the injuries and the diversity in the type of accidents, there are few commonalities between the patients, and care and treatment must be specific to the patient’s needs (4). Military polytrauma is typically caused by: explosive devices and other weapons, such as chemical warfare (14).

Due to the differing nature between military and civilian polytrauma, it is important to examine each separately. Proper care and treatment depends on a thorough understanding of the trauma and the specific needs of the patient. In trauma situations, medical personnel are directly responsible for the immediate and long-term success of patient care. Therefore, a thorough understanding of the types of polytrauma is crucial.

Military Polytrauma

Due to the extreme nature of combat, military personnel are often victims of polytrauma. In recent years, advances in medical interventions and treatment options have resulted in an increase in military personnel who survive combat casualties. However, this has also caused an increase in the number of military personnel who present with polytrauma (15). In previous combat situations, more military personnel would die of the wounds almost immediately and would not be treated for polytrauma. However, there is now a significant increase in the need for polytrauma treatment and care during combat.

Military polytrauma differs from civilian polytrauma in the nature of the trauma, the extent and type of injuries, and the type of accidents that cause the trauma.
(4). It is important for providers to understand the complexity of military polytrauma to better treat patients who are afflicted. Due to the nature of modern warfare and the advances in weaponry, military personnel are afflicted with more advanced, complex injuries, which provide a challenge to providers who must address the multiple needs of the patient (14).

Military polytrauma can result from a variety of combat related accidents. However, the most common causes of military polytrauma are blast related. Blast related trauma is typically the result of contact with improvised explosive devices (IEDs), artillery, rocket and mortar shells, mines, booby traps, aerial bombs and rocket propelled grenades (16). While these are the most common causes of military polytrauma, it is important to understand the other causes of military polytrauma as well, as this will improve the chances of properly managing and treating it.

While the majority of injuries sustained during combat used to occur as a result of gunshot wounds, these numbers have decreased over the past century. Currently, blast trauma is the cause of the majority of polytrauma incidents in military personnel. This is due to advances in weaponry and changes in warfare. From 2003 to 2006, the number of explosion related casualties increased from 56 percent to 76 percent. At the same time, the number of surgeries to treat fragment wounds increased from 48 percent to 62 percent. In fact, since 2009, it is estimated that approximately 80 percent of combat injuries and 90 percent of deaths are a direct result of explosive devises. It is apparent that combat trauma has changed in the past few decades. As a result, the methods of treatment and management have changed as well (14).

Explosions caused by the devices listed above have multiple effects on the body, which is why they typically result in polytrauma for the patient. Common blast related injuries include traumatic brain injury, significant body wounds, infections, severed limbs or spinal cord damage, bone fractures, vision and hearing loss,
and nerve damage (17). In many instances, other injuries can occur, including long-term emotional and behavioral damage. Traumatic Brain Injury (TBI) is one of the most common injuries sustained in blast related trauma. According to the US Department of Veteran’s Affairs, more than sixty percent of blast related trauma result in TBI (17). Therefore, military polytrauma treatment must include an emphasis on TBI, especially as it relates to and impacts other injuries.

The Center for Disease Control (CDC) provides the following table with information regarding the different injuries caused by general blast trauma:

<table>
<thead>
<tr>
<th>System or organ</th>
<th>Injury or condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auditory or vestibular</td>
<td>Tympanic membrane rupture, ossicular disruption, cochlear damage, foreign body, hearing loss, distorted hearing, tinnitus, earache, dizziness, sensitivity to noise.</td>
</tr>
<tr>
<td>Eye, orbit, face</td>
<td>Perforated globe, foreign body, air embolism, fractures.</td>
</tr>
<tr>
<td>Respiratory</td>
<td>Blast lung, hemothorax, pneumothorax, pulmonary contusion and hemorrhage, atrioventricular fistula (source of air embolism), airway epithelial damage, aspiration pneumonitis, sepsis.</td>
</tr>
<tr>
<td>Digestive</td>
<td>Bowel perforation, hemorrhage, ruptured liver or spleen, mesenteric ischemia from air embolism, sepsis, peritoneal irritation, rectal bleeding.</td>
</tr>
<tr>
<td>Circulatory</td>
<td>Cardiac contusion, myocardial infarction from air embolism, shock, vasovagal hypotension, peripheral vascular injury, air embolism-induced injury.</td>
</tr>
<tr>
<td>Central nervous system</td>
<td>Concussion, closed or open brain injury, petechial hemorrhage, edema, stroke, small blood vessel rupture, spinal cord injury, air embolism-induced injury, hypoxia or anoxia, diffuse axonal injury.</td>
</tr>
<tr>
<td>Renal and/or urinary tract</td>
<td>Renal contusion, laceration, acute renal failure due to rhabdomyolysis, hypotension, hypovolemia.</td>
</tr>
<tr>
<td>Extremity</td>
<td>Traumatic amputation, fractures, crush injuries, burns, cuts, lacerations, infections, acute arterial occlusion, air embolism-induced injury.</td>
</tr>
<tr>
<td>Soft tissue</td>
<td>Crush injuries, burns, infections, slow healing wounds.</td>
</tr>
<tr>
<td>Emotional or psychological</td>
<td>Acute stress reactions, PTSD, survivor guilt, post-concussion syndrome, depression, generalized anxiety disorder.</td>
</tr>
<tr>
<td>Pain</td>
<td>Acute pain from wounds, crush injuries, or traumatic amputations; chronic pain syndromes.</td>
</tr>
</tbody>
</table>

(18)
The injuries included in the table are considered general blast related injuries. However, specific injuries will depend upon the type of device used and the environment in which the blast occurs.

It is crucial that military medical providers understand modern warfare, the types of weapons used, and the injuries they cause in order to provide proper combat care. Typically, specific weapon types such as improvised explosive devices cause specific injury patterns that are common and recurrent among patients (19). It is important that combat care providers understand and recognize the patterns of injury caused by these devices and understand how these injuries affect the patient. This will ensure that providers are prepared to treat each patient and maximize the chances of survival.

Blast related trauma is caused by a variety of explosive devices, all of which operate differently. Therefore, it is important to understand the different types of explosive devices prevalent in modern warfare, as it directly affects the injuries sustained and the type of care needed. Explosive devices include artillery, mortars, rockets, grenades, rocket propelled grenades and improvised explosive devices. The most commonly used explosive devices include land mines, rocket propelled grenades, and improvised explosive devices (20).

Explosive devices utilize chemical conversions of liquid or solids into a gas through the generation of energy. This conversion provides the force for the explosive device (21). Explosive devices are categorized as either low or high order depending on the velocity of the detonation. Low and high order devices act differently and exhibit different patterns of injury (14). Therefore, the treatment for patients is different depending on the type of explosive device he or she has come into contact with.
The following table provides examples of low order and high order explosive devices:

<table>
<thead>
<tr>
<th>Low-Order Explosives</th>
<th>High-Order Explosives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamite</td>
<td>Ammonium nitrate</td>
</tr>
<tr>
<td>Gunpowder</td>
<td>Nitroglycerin</td>
</tr>
<tr>
<td></td>
<td>2,4,6-trinitrotoluene (TNT)</td>
</tr>
<tr>
<td></td>
<td>Pentaerythritol tetranitrate (PETN)</td>
</tr>
<tr>
<td></td>
<td>Cyclotrimethylene trinitramine (RDX)</td>
</tr>
<tr>
<td></td>
<td>Cyclotetramethylene tetrinitramine (HMX)</td>
</tr>
<tr>
<td></td>
<td>Nitrocellulose</td>
</tr>
</tbody>
</table>

Low order devices utilize a slow burning process called conflagration to produce their effect. The chemicals present in low order devices are used to propel projectiles, but they can also be used in pipe bombs and petroleum-based bombs. Low order explosives produce a blast wave that is less than 2,000 meters per second, which creates different effects than high order explosives.

High order explosives are characterized by their quick reaction time and the amount of heat and energy they generate. The chemical reaction that occurs in high order explosives creates an extreme rise in pressure that is called a blast wave. This wave moves at approximately 3,000 – 8,000 meters per second. The front of the blast wave produces a shattering effect. The blast wave is so powerful that it propels fragments using extreme force and can cause thermal radiation. Depending on the distance from the detonation site, the effects on the individual will vary. High order explosives often crush soft tissue and bone upon impact. High order explosives also cause blast overpressure injuries, known as barotrauma. The force that is created by the passing of a blast wave can cause immediate amputation of specific body parts, and may even cause evisceration or a complete disintegration of the body. The injuries caused by high order explosives are extreme and affect numerous parts of the individual’s body.
Regardless of the type of explosive device used, blast injuries are categorized based on their effects. Blast injury categories include primary, secondary, tertiary, quaternary, and quinary. The different categories are defined and differentiated based on the mechanism of injury and the effect it has on the body (22). The effects caused by low order explosives are categorized as secondary, tertiary, quaternary, and occasionally quinary effects. The effects caused by high order explosives can be categorized using all five levels.

<table>
<thead>
<tr>
<th>Blast Injury Effects</th>
<th>Mechanism of Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>Injury caused by the effect of the blast wave on the body. Primary blast injury occurs principally in the gas-filled organs and results from extreme pressure differentials developed at body surfaces. Organs most susceptible include the middle ear, lung, brain, and bowel.</td>
</tr>
<tr>
<td>Secondary</td>
<td>Injury caused by flying debris and fragments, propelled mostly by the blast winds generated by an explosion. Most commonly produces penetrating injury to the body. At very close distance to the explosion, debris and fragments may cause limb amputation or total body disruption. This is the most common mechanism of injury from blast.</td>
</tr>
<tr>
<td>Tertiary</td>
<td>Injury results from victim being propelled through space by the blast wind and impacting a stationary object.</td>
</tr>
<tr>
<td>Quaternary</td>
<td>Injury suffered as a result of other effects of bomb blasts, including crush injury from a collapsed structure, inhalation of toxic gases and debris, thermal burns, and exacerbation of prior medical illnesses.</td>
</tr>
<tr>
<td>Quinary</td>
<td>Injury resulting from contamination via biological and chemical agents, radioactive materials, or contaminated tissue from attacker or other person at the scene.</td>
</tr>
</tbody>
</table>

Regardless of type, all explosive devices produce extreme polytrauma. Explosive devices produce distinct patterns of injury that can be easily identified and differentiated from other mechanisms (23). It is imperative that providers understand the specific injury patterns caused by explosive devices in order to ensure successful treatment of the patient. Patients who experience blast trauma typically have increased hypotension, more significant injury severity, and extended care needs in comparison to other trauma patients (24).
Improvised Explosive Devices

Improvised Explosive Devices (IED’s) are responsible for a majority of blast trauma cases in military personnel. In fact, IEDs produced 40 – 60 percent of casualties in Iraq and 50 – 75 percent in Afghanistan from 2006 – 2009.

According to the United States Marines, Improvised Explosive Devices are defined as “devices that are placed or fabricated in an improvised manner incorporating destructive, lethal, noxious, pyrotechnic, or incendiary chemicals and designed to destroy, incapacitate, harass, or distract. They may incorporate military weapons, but are normally devised from non-military components.”

Improvised Explosive Devices are “placed or fabricated in an improvised manner incorporating destructive, lethal, noxious, pyrotechnic, or incendiary chemicals and are designed to destroy, incapacitate, harass, or distract.” While IEDs occasionally utilize military weapons as part of their design, they are typically built using non-military pieces. Insurgents and terrorists often use IEDs. Therefore, their design can vary, as they are comprised of various parts and pieces that are not formulaic. IEDs are diverse in their shape and size and can be created in a number of forms. They range in size from a cigarette pack to an explosive equipped vehicle. They can be produced easily and provide a quick and easy way to create an explosion. IEDs are easy to conceal as they can be created in any type of container. They can be produced using a wide range of explosive materials, and they can be detonated in a variety of ways.

The following provides examples of the ways in which IEDs can be concealed, deployed and detonated:

- Casings, ranging in size from a cigarette pack to a large vehicle, are used to hide the IED and possibly provide fragmentation. Small or large packages, including 120-mm and larger artillery or mortar projectiles with armor-piercing capability, are often placed in potholes covered with dirt,
behind cinder blocks or sand piles to direct the blast, hidden in garbage bags or animal carcasses, or thrown in front of vehicles.

- Common hardware such as ball bearings, bolts, nuts, or nails can be used to enhance the fragmentation. Propane tanks, fuel cans, and battery acid has been added to IEDs to increase their blast and thermal effects. The damaging effects of IEDs can be maximized via coupling (linking one munition to another), boosting (stacking one munition upon another), and daisy-chaining (many munitions physically and temporally linked together length-wise).

- Triggers can be command-detonated by a remote device such as a cell phone, car alarm, toy car remote, or garage door opener, or with a time-delay device to allow the bomber to escape or to target military forces operating in a pattern. The initiator almost always includes a blasting cap and batteries as a power source for the detonator.

- Person-borne or victim-actuated devices (suicide bombs), typically using a powerful explosive with enhanced fragmentary effects, are employed to kill or maim as many people as possible. These are concealed in clothing worn by the assailant and hand-detonated.

- Vehicle-borne devices can vary in size from 100 to 1,000 pounds, depending on the size of the vehicle. The explosive charge can include mortar and artillery rounds, rocket mortars, warheads, and plastic explosive no. 4 (PE4). These can be concealed in vehicles of all types (cars, trucks, donkey carts). They can be deployed singly or in multiple vehicles. A lead vehicle is used to slow traffic and is followed by the main explosive device to maximize casualties. Detonation is by a command firing system.

- IEDs can be engineered to overcome IED detection measures through rolling (i.e., a target vehicle rolls over an initial unfused munition and then triggers a second trailing munition, which in turn detonates the initial munition). This sequencing positions the second (and most damaging) explosion directly under the target vehicle (14).
Types of IEDs

Since IEDs can be made out of a variety of materials, there are a number of different common devices used. The following is a list of the most common IEDs that are currently being used:

- Vehicle Borne Bombs
- Suicide Bombs
- Roadside Explosives
- Explosively Formed Projectiles (26)

Although the IEDs listed above are the most common, new and improved IEDs are being developed and deployed constantly. This is due to the need for more advanced devices that can penetrate the protective shields of new military tanks and combat gear. These IEDs produce an even greater impact and cause severe trauma in military personnel who come into contact with them (14). These newer IEDs are known as antitank munitions as they are directly intended to be used against the highly advanced military tanks. Antitank munitions are categorized in three ways: (1) shaped-charges; (2) kinetic energy rounds; and (3) antitank landmines (14).

IED Injury

Due to the blast wave caused by IEDs, they cause significant trauma to an individual who comes into contact with them (27). Although IEDs differ in shape, size and detonation, they produce some common injury patterns. In numerous studies conducted on victims of IEDs, data showed that the devices produced complex injuries in all individuals who came into contact with them (21). In addition, IEDs produced a 50 percent mortality rate (27). Therefore, it is important to understand IEDs and the impact they have in individuals who come into contact with them.

The injury patterns caused by IEDs are dependent on a number of factors, including the composition and type of bomb, the delivery method, the distance
between the victim and the blast, whether the blast occurred in a closed or open space, and any surrounding environmental barriers or hazards (24).

Using the blast injury categories listed above, IED injuries can be categorized as follows:

<table>
<thead>
<tr>
<th>Category</th>
<th>Characteristics</th>
<th>Body Part Affected</th>
<th>Types of Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>Unique to HE, results from the impact of the over-pressurization wave with body surfaces.</td>
<td>Gas filled structures are most susceptible - lungs, GI tract, and middle ear.</td>
<td>Blast lung (pulmonary barotrauma) TM rupture and middle ear damage Abdominal hemorrhage and perforation - Globe (eye) rupture - Concussion (TBI without physical signs of head injury)</td>
</tr>
<tr>
<td>Secondary</td>
<td>Results from flying debris and bomb fragments.</td>
<td>Any body part may be affected.</td>
<td>Penetrating ballistic (fragmentation) or blunt injuries Eye penetration (can be occult)</td>
</tr>
<tr>
<td>Tertiary</td>
<td>Results from individuals being thrown by the blast wind.</td>
<td>Any body part may be affected.</td>
<td>Fracture and traumatic amputation Closed and open brain injury</td>
</tr>
<tr>
<td>Quaternary</td>
<td>All explosion-related injuries, illnesses, or diseases not due to primary, secondary, or tertiary mechanisms. Includes exacerbation or complications of existing conditions.</td>
<td>Any body part may be affected.</td>
<td>Burns (flash, partial, and full thickness) Crush injuries Closed and open brain injury Asthma, COPD, or other breathing problems from dust, smoke, or toxic fumes Angina Hyperglycemia, hypertension</td>
</tr>
</tbody>
</table>

(18)
IEDs cause complex injuries throughout the body. However, they have significant impact on the following systems:

- Auditory
- Eye, Orbit and Face
- Respiratory
- Digestive
- Circulatory
- CNS
- Renal
- Extremities (21)

The injuries to the systems are common among the different types of IEDs. While the devices may be different, the blast they produce impacts victims similarly. It is important to understand the specific injuries IEDs can cause to the systems listed above.

According to the Center for Disease Control, the following injuries are common results of IEDs:

<table>
<thead>
<tr>
<th>System</th>
<th>Injury or Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auditory</td>
<td>TM rupture, ossicular disruption, cochlear damage, foreign body</td>
</tr>
<tr>
<td>Eye, Orbit, Face</td>
<td>Perforated globe, foreign body, air embolism, fractures</td>
</tr>
<tr>
<td>Respiratory</td>
<td>Blast lung, hemothorax, pneumothorax, pulmonary contusion and hemorrhage, A-V fistulas (source of air embolism), airway epithelial damage, aspiration pneumonitis, sepsis</td>
</tr>
<tr>
<td>Digestive</td>
<td>Bowel perforation, hemorrhage, ruptured liver or spleen, sepsis, mesenteric ischemia from air embolism</td>
</tr>
<tr>
<td>Circulatory</td>
<td>Cardiac contusion, myocardial infarction from air embolism, shock, vasovagal hypotension, peripheral vascular injury, air embolism-induced injury</td>
</tr>
</tbody>
</table>
While IEDs cause trauma to all of the areas listed above, the most commonly affected areas include the lungs, ears, abdominal region and brain (17). Of these, Traumatic Brain Injury (TBI) is the most common, affecting approximately 60 percent of those who come into contact with IEDs (28). An understanding of the most common IED injuries is crucial for those who provide combat care, as treatment is dependent upon addressing all of the needs of the patient and mitigating the affects of the blast.

The Center for Disease Control control provides the following descriptions of the most common IED blast injuries:

**Lung Injury**

“Blast lung” is a direct consequence of the HE over-pressurization wave. It is the most common fatal primary blast injury among initial survivors. Signs of blast lung are usually present at the time of initial evaluation, but they have been reported as late as 48 hours after the explosion. Blast lung is characterized by the clinical triad of apnea, bradycardia, and hypotension. Pulmonary injuries vary from scattered petechiae to confluent hemorrhages. Blast lung should be suspected for anyone with dyspnea, cough, hemoptysis, or chest pain following blast exposure. Blast lung produces a characteristic “butterfly” pattern on chest X-ray. A chest X-ray
is recommended for all exposed persons and a prophylactic chest tube (thoracostomy) is recommended before general anesthesia or air transport is indicated if blast lung is suspected.

Ear Injury
Primary blast injuries of the auditory system cause significant morbidity, but are easily overlooked. Injury is dependent on the orientation of the ear to the blast. TM perforation is the most common injury to the middle ear. Signs of ear injury are usually present at time of initial evaluation and should be suspected for anyone presenting with hearing loss, tinnitus, otalgia, vertigo, bleeding from the external canal, TM rupture, or mucopurulent otorhea. All patients exposed to blast should have an otologic assessment and audiometry.

Abdominal Injury
Gas-containing sections of the GI tract are most vulnerable to primary blast effect. This can cause immediate bowel perforation, hemorrhage (ranging from small petechiae to large hematomas), mesenteric shear injuries, solid organ lacerations, and testicular rupture. Blast abdominal injury should be suspected in anyone exposed to an explosion with abdominal pain, nausea, vomiting, hematemesis, rectal pain, tenesmus, testicular pain, unexplained hypovolemia, or any findings suggestive of an acute abdomen. Clinical findings may be absent until the onset of complications.

Brain Injury
Primary blast waves can cause concussions or mild traumatic brain injury (MTBI) without a direct blow to the head. Consider the proximity of the victim to the blast particularly when given complaints of headache, fatigue, poor concentration, lethargy, depression, anxiety, insomnia, or other
constitutional symptoms. The symptoms of concussion and post traumatic stress disorder can be similar. (24)

Rocket Propelled Grenades
Rocket Propelled Grenades (RPGs) are commonly used during combat and they produce significant trauma in those who come into contact with them. RPGs are muzzle-loaded weapons that are often used against armored military vehicles and ground personnel. RPGs are shoulder fired and vary in shape, size and firing type (14). Typically, RPGs are used to fire fragmentation and high explosive rounds that will result in a lethal blast with a radius of approximately four meters (26). Due to the diverse nature of RPGs, the effects can vary. However, in most cases, the injuries sustained are severe (29).

Rocket Propelled Grenades are popular weapons that are commonly used to destroy armored tanks. Rocket Propelled Grenades are used frequently as they are inexpensive and easy to use. They are very effective against armored vehicles and provide a means to attack military personnel who would normally be relatively protected during combat. The RPG fires an unguided rocket that is equipped with an explosive warhead. Since the rocket is unguided, there can be problems with accuracy, which requires that they be fired at close range (14). This results in additional damage and injuries for both the victim as well as the individual firing the RPG.

Since RPGs are deployed at close contact, they produce different injuries than explosives that are deployed at long ranges (27). Typical RPG injuries are similar to other blast related injuries and include traumatic brain injury, limb loss, burns, bone fractures, lung injury, ear injury, and abdominal injury (18). Actual injuries will differ depending on the size and shape of the rocket propelled grenade as well as the point of impact (14).
Other Weapons

Improvised Explosive Devices and Rocket Propelled Grenades are two of the most common devices used against military personnel and are responsible for a majority of the casualties. However, there are other devices that are used during combat that also cause severe trauma in patients. These devices must be identified and understood to ensure that military personnel receive proper treatment and care.

Landmines

Landmines are frequently used during combat and they can cause significant injuries. Landmines are explosive devices that are located on or underground. When they are triggered, typically by being stepped on, they explode. The explosion is most often created by electromagnetic waves or through direct pressure (14). Landmines are favored during combat situations as they are easy to place and they can cause severe damage (26). Landmines have been prevalent in both the Iraq and Afghanistan wars. In fact, there are approximately 10 million landmines currently employed in Afghanistan (14).

There are three primary types of landmines that are currently in use. They are blast or static, bounding fragmentation, and directional fragmentation (26). While each type of landmine can cause severe damage, each category has a specific associated pattern of injury. All landmines cause injury through blast effects and they fall within the following categories: primary blast effect, secondary fragments, tertiaty, and quaternary.

The following table provides information on the three types of landmines (14):

<table>
<thead>
<tr>
<th>Type of Mine</th>
<th>How Concealed</th>
<th>How Detonated</th>
<th>Primary Areas of Wounding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blast or static</td>
<td>Buried just below ground surface</td>
<td>Pressure (e.g., being stepped upon)</td>
<td>Foot, upper leg, lower leg</td>
</tr>
<tr>
<td>Fragmentation Bounding</td>
<td>Buried just below surface with fuse protruding, or laid on</td>
<td>Fuse or tripwire</td>
<td>All</td>
</tr>
</tbody>
</table>
**Directional**

<table>
<thead>
<tr>
<th>surface</th>
<th>Electrical charge, timed fuse, or tripwire</th>
<th>All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laid on surface</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Blast (Static) Landmines**

Blast, or static, landmines are mines designed to detonate when an individual steps on them (26). They are very small and are often difficult to identify. Blast landmines are intended to injure the person that steps on them. However, the effects are often fatal due to immediate injury or later complications such as hemorrhage (17).

Blast landmines produce two specific patterns of injury. The first is complete, or almost complete, amputation of the extremity. Due to the impact of the blast, the foot (and occasionally the entire leg) is removed upon impact (29). In many instances, the impact results in the partial removal of the extremity, which requires further amputation during treatment (30). The second injury pattern is random penetrating fragment injuries that occur along the tissue and fascial planes of the lower leg. This occurs when particles such as dirt, debris, bone fragments, and other foreign objects are driven into the leg and other soft tissue by the blast (29). This causes significant destruction to the leg and requires immediate treatment. These injuries often require amputation (22).

**Fragmentation Landmines**

Fragmentation landmines are broken into two categories: bounding fragmentation landmines and directional fragmentation landmines (14). Bounding fragmentation landmines are characterized by the direction they deploy. They “bound” upward and explode mid air. This results in an explosion at the torso level rather than at the ground level. When a bounding fragmentation landmine is detonated, it propels hundreds of fragments in various directions at very high speeds. The fragments can travel hundreds of meters, thereby causing injury to others (26). Bounding fragmentation landmines cause injuries to areas higher on the body, such as the torso, neck, and upper
extremities (24). Bounding fragmentation landmines cause the highest number of fatalities of all landmines, and the injuries sustained by those who survive are extensive and severe (18).

Directional Fragmentation Landmines differ from bounding fragmentation landmines in that they project the fragments in a single, specific direction. While bounding fragmentation landmines can send fragments all over, directional fragmentation landmines are designed to send fragments in one specific, pre-determined direction (14). This enables the attacker to identify a target and arrange the landmine to attack that specific target. Directional fragmentation landmines can spray fragments in an arc over a specific point, thereby causing damage to a number of spots on the body, rather than just the upper or lower extremities (14). Therefore, the damage caused by directional fragmentation landmines can be extensive and often produces a high level of trauma in the individual (18).

While the devices listed above are the most common causes of polytrauma in military personnel, other military weapons can produce trauma. Artillery, booby traps, and other blast producing weapons can cause extensive damage to an individual who comes into contact with them (14). These devices do not produce the same injury patterns as the devices listed above, as the injuries are dependent upon how the device is used and they ways in which it is detonated.

Military polytrauma differs from other types of polytrauma due to the nature of the injuries and the devices used. While some of the injuries caused by blast trauma are similar to those caused by civilian related accidents, they impact the patient differently. Military trauma occurs during combat and can produce significant damage to the individual. Due to the strength and explosive capacity of various weapons and explosive devises, the trauma to the body is often widespread and requires significant treatment to repair. In most instances, military trauma patients experience severe disfigurement due to the damage caused (4). In
addition to physical trauma, instances of military polytrauma also include psychological and emotional trauma as the extreme nature and cause of the injuries is incredibly distressing (31).

Civilian Polytrauma
Civilian polytrauma is the result of a variety of accidents and mechanisms, including but not limited to: motor vehicle accidents, industrial accidents, sport accidents, gunshots, violent crimes, suicide attempts and natural catastrophes. Ultimately, any accident or event that can cause severe damage to an individual has the potential to cause polytrauma (32). Unlike military polytrauma, which is the direct result of specific weaponry, civilian polytrauma is difficult to categorize (4). Military devices produce specific patterns of injury, while civilian accidents can produce a variety of effects and injuries depending upon the situation. Therefore, it is more difficult to establish standard protocol for civilian polytrauma (12). Patients must be assessed and treated on an individual basis.

Motor Vehicle Accidents
Motor vehicle accidents are known to account for the highest number of polytrauma cases in the United States (33). The US Department of Transportation breaks motor vehicles into the following categories:

- Passenger Car
- Light Truck – Van
- Light Truck – Utility 1,583
- Light Truck
- Motorcycles
- Large Trucks (34)

When discussing polytrauma caused by motor vehicle accidents, all of the types listed above are include. In 2009, approximately 2.3 million adults were admitted to emergency departments for treatment for injuries sustained during a motor vehicle accident (35). Most injuries sustained during a motor vehicle accident
cause significant trauma to the patient as they impact a number of areas on the body. In addition, motor vehicle accidents are one of the leading causes of death in the United States (36). Motor vehicle accidents that cause injuries are often severe and result in significant damage to the driver and passengers (35). Due to the blunt force caused by the accident, as well as the amount of flying debris caused by breaking glass, shards of metal and other random objects, injuries often occur both internally and externally (37). Many injuries sustained during a motor vehicle accident cause permanent damage and often result in a significant lifelong disability (4).

While motor vehicle accidents pose a significant risk of causing polytrauma, the chances are increased by a number of factors.

- **Increased Speed:**
  Increased speed has a direct impact on the potential for a crash as well as the amount of damage and severity of injuries that result from the crash.

- **Drinking and Driving:**
  Drinking and driving often increases the severity and type of injuries caused. Intoxicated drivers and passengers are also at a higher risk of sustaining severe injuries due to their limited response time and relaxed physical state.

- **Seat Belts and Child Restraints:**
  Many drivers and passengers choose not to wear a seatbelt or a proper child restraint system. Not being properly secured in the vehicle can cause the individual to be propelled from the vehicle, most often through the windshield or other window, during an accident. If an individual is not propelled through the windshield, he or she will still be thrown around the vehicle during the accident, which can cause additional injuries.

- **Helmet Use (Motorcycles):**
  Motorists who fail to wear a helmet when riding on a motorcycle risk sustaining severe head injuries during an accident. The motorist is not protected in any way during a motorcycle crash, and the blunt trauma that
occurs to the head without the protection of a helmet is severe and significant. According to the World Health Organization, wearing a helmet during a motorcycle accident reduces the chance of a severe injury by approximately 70 percent.

- **Distracted Driving:**
  While distracted driving directly increases the chances of a motor vehicle accident, it is also responsible for increasing the chances that the motorist will sustain more severe injuries. Distracted driving can occur for a variety of reasons, including the use of mobile devices, not paying attention to the road, talking to other motorists, applying make up, etc. However, the most common cause of distracted driving is the use of mobile devices. Drivers who use mobile devices when driving are at an increased risk of sustaining severe injuries, as the driver is not properly engaged with the vehicle (33).

Motor vehicle accidents do not have a specific pattern of injury, but there are some injuries that are most common among motor vehicle accident victims. The Department of Motor Vehicles defines severe injuries as the following: skull fractures, internal injuries, broken or distorted limbs, unconsciousness, severe lacerations, and unable to leave the scene without assistance (38). Many motor vehicle accidents result in traumatic brain injury and the loss of limbs (33). Internal organ damage is also common due to the impact caused by the accident (7). Many of the injuries sustained during motor vehicle accidents result in long-term complications and disability (39).

**Firearms**
Ballistic trauma, which is the trauma caused by firearms, is often severe, if not fatal. There are approximately 500,000 gunshot wounds per year in the United States, and these wounds typically cause severe damage (40). The amount and severity of injury caused by firearms depends on a number of factors, such as:
- Type of weapon/bullet used
• Distance from weapon
• Location and trajectory/path of injury
• Permanent vs. temporary cavity (41)

All firearm injuries are not the same. Injury and trauma level depends on the type of firearm used. Typically, firearm injuries are categorized as either low velocity injuries or high velocity injuries, and they are classified based on the type of firearm used and the projectile impact that is caused (14). Low velocity injuries are primarily caused by firearms with a muzzle velocity of less than 600 meter per second (m/s). Most low velocity firearm injuries are caused by handguns and are more prevalent than other types of injuries (40). High velocity injuries are caused by firearms with a muzzle velocity of more than 600 meter per second. Most high velocity injuries are caused by military weapons, or high-powered hunting rifles (14).

Injury severity and pattern differs depending on whether it is a low velocity injury or a high velocity injury. According to Lichte et al.,

Two areas of projectile-tissue interaction have to be differentiated: the permanent and the temporary cavity. In low-velocity bullets the direct tissue destruction with its localized area proportional to the size of the projectile plays the major role, whereas in high-velocity injuries the lateral tissue expansion ("cavitation") becomes more important. After passage of the projectile there is a transient lateral displacement of tissue, which can reach the 10 to 40-fold diameter of the bullet. If the projectile crosses elastic tissue, such as skeletal muscle, blood vessels and skin, this tissue may be pushed aside after passage of the bullet, but then rebound. In cases of inelastic tissue, such as bone and liver, fractures and tissue destruction can be the consequence (40).
Gunshots cause injuries upon impact and can affect all different parts of the body depending on the location of initial impact. Therefore, multiple traumas can occur externally and internally and may be located in one specific area of the body, such as the head or the chest (42). However, when a bullet makes impact with the body, it can produce extensive damage as it moves throughout the body. Upon initial impact, the bullet crushes the tissue of the individual. From there, the bullet propels forward and creates a tunnel that expands throughout the path of projection to create a larger tunnel. The tunnel is temporary, but it causes damage to the tissue and ligaments in the surrounding areas. Damage is caused by compression, deformation and shear force. Once the bullet has passed through the temporary cavity, the cavity decreases in size and returns to normal. However, the bullet does leave behind a permanent cavity in the location of cavitation. The tissue in this area will be permanently damaged (43).

Damage is often dependent on the type of bullet used. Bullets that are encased with hard shells produce deeper penetration and more significant cavitation. Bullets with soft or hollow points typically deform or fragment and often ricochet inside the body (14). This can produce damage to more areas. The actual injuries are influenced by a number of factors, including the point of entry and the distance that the victim is from the weapon (44). Some guns, such as shotguns, contain small pellets that spread apart when they are released from the barrel. This produces a blast that spreads over a larger area and will often cause damage to numerous areas of the body rather than one specific point of entry. However, these produce less damage when fired from a greater distance (40).

Gunshot wounds are not limited to the point of entry. Gunshots also have the potential to create exit wounds as the bullet may leave the body after tunneling through (41). In addition, gunshots can produce contact wounds, which occur when a gun is held directly against the skin. Exit wounds can be more severe than entrance wounds as the bullet often expands within the body (14).
The impact of the bullet, the path it takes, and the injuries it causes are dependent upon a number of factors. If a bullet deforms or fragments once it enters the body, it can cause damage to numerous bones and organs (42). In addition, different parts of the body are more resilient and have enough elasticity to incur less damage than those parts that are more rigid. If organs are filled with fluid, such as the heart, bowels, and bladder, they are prone to rupture upon impact (40). Bones are rigid and often fragment upon impact (42).

The following chart, provided by Emergency Medical Services (EMS) World, lists the different types of gunshot injuries by location. Most patients experience trauma in a number of regions and often present with internal and external injuries due to the impact caused by the bullet and the force of the shot.

**Gunshot Wound Signs & Symptoms**

<table>
<thead>
<tr>
<th>Injury location</th>
<th>Signs &amp; symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>External bleeding, deformity of the head, fluid in the ears/nose</td>
</tr>
<tr>
<td>Neck</td>
<td>External bleeding, tracheal shifting, deformity, JVD, tracheal tugging, bruising, crepitus, raspy voice</td>
</tr>
<tr>
<td>Tracheobronchial/lung</td>
<td>Subcutaneous emphysema, cough, respiratory distress, hemoptysis (usually secondary to a disrupted bronchial artery), tension pneumothorax, intercostal retractions, decreased breath sounds, hyperresonance, tachypnea, agitation, hypotension, tachycardia, hypoxia, shifting of the trachea and apical heartbeat away from the injured side</td>
</tr>
<tr>
<td>Carotid artery</td>
<td>Decreased LOC, contralateral hemiparesis, hemorrhage, hematoma, dyspnea (secondary to compression of the trachea), pulse deficits</td>
</tr>
<tr>
<td>Jugular vein</td>
<td>Hematoma, external hemorrhage, hypotension</td>
</tr>
<tr>
<td>Esophagus, pharynx</td>
<td>Dysphagia, bloody saliva, sucking neck wound, pain and tenderness in the neck, crepitus</td>
</tr>
<tr>
<td>Abdomen</td>
<td>Bruising, distension, rigidity, external hemorrhage, self-splinting</td>
</tr>
</tbody>
</table>
Pelvis | Bruising, external bleeding, deformity, crepitus
---|---
Extremities | Bruising, open wound, external bleeding, crepitus, deformity, decreased or absent distal pulse, reduced or absent sensation, delayed capillary refill time

(42)

Other Causes
Motor vehicle accidents and gunshot wounds are the two main causes of polytrauma in civilians. However, polytrauma can be caused by a variety of other incidents. Ultimately, any accident or event that leads to multiple injuries is considered to have caused polytrauma. However, there are some more common causes of polytrauma. The following is a list of the various types of accidents that are known to result in polytrauma:

- Suicide attempts
- Bicycle accidents
- Catastrophes
- Falls
- Industrial and Occupational accidents
- Sports Related accidents

The accidents listed above produce different types of trauma and cannot be easily defined as they differ depending on outside circumstances. However, it is still necessary to understand how these accidents cause trauma to the patient so that the provider is more able to provide emergency and long-term treatment and care.

Suicide Attempts
Due to the diverse nature of suicide, there is no distinct pattern of injury for those who make the attempt. In most instances, the injury and trauma will be similar to other accidents as the mechanism used is what causes the trauma (9). For example, if an individual attempts suicide using a handgun, the resulting injuries
will be similar to those experienced by other individuals who have been the recipients of gunshot wounds. However, they will also differ, as the point of entry will be different due to the fact that it is self-induced. In other instances, the suicide attempt will produce distinct injuries that do not fall within another category. Individuals who attempt suicide by hanging will experience trauma that is specific to the attempted hanging, which is not a common occurrence outside of suicide attempts (5).

Ultimately, suicide attempts produce injuries that are specific to the mechanism used, and it is important to understand how each mechanism causes trauma in order to effectively treat and care for the damage incurred. The following are the most common methods of attempting suicide:

- Jumping from a high location
- Taking an overdose of pills or ingesting poison
- Hanging oneself
- Attempted gunshots to the head or chest
- Overdose of specific drugs
- Slitting one’s wrists (45)

The methods listed above produce a variety of injuries as they differ greatly from each other. However, what they have in common is that they typically produce significant trauma to the patient. For example, jumping from a high location can cause severe damage to the extremities and internal organs of the patient, much like a fall can (46). Drug overdoses can cause extensive internal damage, but will produce few external injuries (48). An attempted hanging will restrict blood flow to the brain and will most likely cause severe brain damage (45). However, it can also result in damage to the neck and other limbs due to the pressure and impact that the neck and spine incur (45). It is important to understand the different injuries that can be caused by suicide attempts and identify the impact they will have on the patient’s treatment and care.
Bicycle Accidents
Bicycle accidents are one of the leading causes of polytrauma since the individual is often wearing little to no protective gear (48). Bicycle accidents can occur as the result of a number of different factors, including but not limited to "rider errors (losing control, speed, performing stunts, inexperience), motorist errors, environmental hazards (objects in the road, loose gravel) or bicycle mechanical failure. (49)" Due to the extent of the bicycle accident and the blunt impact, the patient often experiences severe trauma. In most instances, the injuries will be both internal and external (48). Treatment for bicycle injuries will vary, as it is dependent on the type of injury sustained and the immediacy of the treatment needs.

Bicycle accidents are directly responsible for a number of polytrauma cases each year, especially in children and adolescents. According to American Family Physician:

"Bicycle-related injuries account for approximately 900 deaths, 23,000 hospital admissions, 580,000 emergency department visits and more than 1.2 million physician visits per year in the United States, resulting in an estimated cost of more than $8 billion annually. The Child Health Supplement to the 1988 National Health Interview Survey estimated that approximately 4.4 million children aged five to 17 years were injured annually because of participation in sports and recreation; bicycle-related injuries were responsible for 10 to 40 percent of these (49)."

While there is no standard pattern of injury for bicycle accidents, there are some common injuries that bicyclists frequently experience as a result of accidents.

In some instances, the bicycle accident will be minimal enough that the individual will only experience minor skin abrasions and lacerations (48). However, many bicycle accidents will be severe enough to cause significant trauma to the patient. In those instances, many of the external and internal areas can be
The following table provides information regarding common bicycle related injuries. This table, below, only includes information regarding significant injuries.

<table>
<thead>
<tr>
<th>Body Part</th>
<th>Injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>Skull fracture, concussion, brain contusion, intracranial hemorrhage</td>
</tr>
<tr>
<td>Face/eye</td>
<td>Contusions, facial fractures, dental fractures, corneal foreign bodies</td>
</tr>
<tr>
<td>Musculoskeletal</td>
<td>Fractures, dislocation, strains</td>
</tr>
<tr>
<td>Chest</td>
<td>Rib fractures, parenchymal lung injury</td>
</tr>
<tr>
<td>Abdomen</td>
<td>Splenic rupture, hepatic laceration, renal contusion, pancreatic trauma, vascular perforation, small or large bowel contusion, rupture, traumatic hernia</td>
</tr>
<tr>
<td>Genitourinary</td>
<td>Urethral and vulval trauma, rectal trauma, pelvic fractures</td>
</tr>
</tbody>
</table>

Head injuries, such as traumatic brain injury and bone fractures, are the most common injuries sustained during a bicycle accident. The amount of trauma to the head can be minimized by the use of a bicycle helmet (48). In instances where the cyclist is not wearing a helmet, the amount of trauma to the head can be extreme and often results in severe traumatic brain injury. When a cyclist wears a helmet, there is still a chance that he or she will experience traumatic brain injury. However, the trauma is typically less severe and does not have as significant of an impact (49). Bone fractures can be quite severe, especially when they occur in the pelvic area. In fact, pelvic fracturing and shattering is a common bicycle related injury (7).

**Catastrophes**

Catastrophes such as hurricanes, tornadoes, earthquakes, floods, lightening, fires, and other such events, can cause severe trauma due to the impact and extreme force they cause. Depending on the type of catastrophe, individuals can experience trauma to different areas of the body. Events such as hurricanes and tornadoes can produce extreme levels of wind and flying debris is most often the cause of injuries and trauma (50). Individuals may also be buried under debris.
and fallen objects. During earthquakes, individuals are most at risk of being crushed under fallen objects or receiving injuries as the result of objects falling on them (51). In lightening strikes, individuals will experience shock to the internal systems as well as burns due to the energy and heat produced (50). Fires will cause extensive burns to the individual as well as significant lung and ocular damage (51). Since different catastrophes will result in different types of injuries, treatment will depend on the patient needs.

_Falls_
While most falls that occur over short distances do not cause trauma, falls that occur over a significant distance can produce severe trauma and often result in death. Due to the blunt force caused by impact, a fall will cause extensive damage both internally and externally (52). Most of the fall related trauma cases occur in young children. In fact, according to the Center for Disease Control, falls are the leading cause of unintentional injury in children and children under the age of fourteen and account for one third of all fall related injuries and emergency room treatment (53). The majority of fall related injuries in children are caused by falling out of windows, playground accidents and nursery related accidents (falling off a changing table or out of the crib) (52). In adults, the majority of falls occur as a result of work related accidents, hiking accidents, ladder accidents and any other situation that involves being poised at a significant height (53).

Regardless of the cause of the fall, the distance of the fall and the type of surface the individual lands on determines the severity of the injury. Head injuries are the most common fall related injuries, and they often result in death (53). Other common fall related injuries include neck and spinal injuries, broken bones and fractures, and internal organ damage (52).

_Industrial and Occupational Accidents_
Industrial and occupational accidents include a variety of different events and have differing effects on the individual. Industrial accidents account for the
majority of occupational related accidents (54). However, many different occupations pose a risk of accidents that can result in trauma. Due to the vast differences between occupations, it is difficult to categorize and define occupational trauma. Each occupation poses its own risk. Treatment will depend on the type of accident.

In the case of industrial occupations, individuals typically sustain injuries from coming into contact with machines. In many cases, trauma is caused when an individual falls into or is pulled into a machine (55). This often results in extensive damage to the internal organs and bones. Traumatic brain injury is quite common in these accidents as well (56). Other industrial accidents involve contact with chemicals. These accidents typically cause extensive trauma to the external body parts, as well as ocular damage. Accidents involving machines and chemicals are the most common industrial accidents and produce the majority of trauma cases (55). However, any accident that occurs in an industrial workplace has the potential to result in trauma.

Other occupations also pose a risk of accidents that can cause severe trauma. The construction trade is highly dangerous and is responsible for a number of occupational trauma cases. According to the Occupation Health and Safety Administration (OSHA), there are four distinct causes of death and severe injury in the construction industry. These injuries include:

- **Falls** - Construction workers are often situated well above the ground while they are working. Therefore, the highest incidence of workplace injuries occurs as the result of falls. Falls result in both internal and external trauma. Common fall related injuries include head trauma, broken bones, and internal organ damage.
- **Electrocutions** - Due to the nature of the construction trade, many workers are in contact with live electricity. Therefore, the number of injuries sustained from electrocution is quite high. Electrocution primarily causes
internal injuries and neurologic trauma. However, if the electrical shock is significant, the individual may sustain burns.

- **Struck by Object** - Individuals are often struck by objects as part of construction work. These objects may be small flying objects or they may be large falling objects. Each type of flying object will inflict different types of damage on the individual. Smaller objects will often pierce the skin and may also cause trauma to internal organs. Large objects have the potential to crush the individual and cause severe head trauma and bone fractures.

- **Caught-in/between** - Much like industrial accidents, construction accidents are often caused when an individual falls into a machine or when the individual is crushed between two objects. This will cause severe internal damage and may also result in traumatic brain injury (57).

In addition to industrial and construction related accidents, other occupations pose a risk for trauma inducing accidents. According to the Bureau of Labor Statistics, the following occupations had the highest rates of non-fatal injuries in 2011:

<table>
<thead>
<tr>
<th>Industry</th>
<th>NAICS Code</th>
<th>2011 Annual average employment (thousands)</th>
<th>Incidence rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire protection (Local Government)</td>
<td>92216</td>
<td>235.4</td>
<td>13.5</td>
</tr>
<tr>
<td>Nursing and residential care facilities (State Government)</td>
<td>623</td>
<td>139.6</td>
<td>513.1</td>
</tr>
<tr>
<td>Steel foundries (except investment) (Private Industry)</td>
<td>331513</td>
<td>17.0</td>
<td>12.7</td>
</tr>
<tr>
<td>Ice manufacturing (Private Industry)</td>
<td>312113</td>
<td>7.3</td>
<td>11.9</td>
</tr>
<tr>
<td>Industry Description</td>
<td>NAICS Code</td>
<td>Employment</td>
<td>Earnings</td>
</tr>
<tr>
<td>-----------------------------------------------------------</td>
<td>------------</td>
<td>------------</td>
<td>----------</td>
</tr>
<tr>
<td>Skiing facilities (Private Industry)</td>
<td>71392</td>
<td>36.2</td>
<td>11.5</td>
</tr>
<tr>
<td>Police protection (Local Government)</td>
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<td>510.9</td>
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<td>101.7</td>
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<td>Truck trailer manufacturing (Private Industry)</td>
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<td>8.6</td>
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<tr>
<td>Consumer electronics and appliances rental (Private Industry)</td>
<td>53221</td>
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<td>8.6</td>
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NOTES:
1. The incidence rates represent the number of injuries and illnesses per 100 full-time workers and were calculated as: (N/EH) x 200,000, where:
   N = number of injuries and illnesses
   EH = total hours worked by all employees during the calendar year
   200,000 = base for 100 equivalent full-time workers (working 40 hours per week, 50 weeks per year)
2. High rate industries were those having the highest incidence rate of total recordable cases of injuries and illnesses and at least 500 total recordable cases at the most detailed level of publication, based on the North American Industry Classification System — United States, 2007.
4. Employment is expressed as an annual average and is derived primarily from the BLS-Quarterly Census of Employment and Wages (QCEW) program.
5. A statistical significance test indicates that the difference between the 2011 incidence
rate and the 2010 rate is statistically significant at the 95 percent confidence level.
6. Excludes farms with fewer than 11 employees. (54)

Some of the occupations listed in the table above do not typically cause severe trauma. However, there are some specific occupations that are known to pose the threat of severe injury. These include emergency personnel: fire, police, and other emergency workers; as well, agricultural workers, lab technicians, and environmental workers (54).

Sports Related Accidents
Most sports related accidents do not cause polytrauma. However, some accidents have the potential to do so. These accidents typically involve a blunt force from physical contact or an injury caused by a fall (58). Physical contact sports such as football and hockey pose the risk of severe head and neck injury due to the impact caused from hitting into another player of from hitting objects such as the wall or the ground (59). While most of the injuries caused during these accidents cannot be classified as polytrauma, there are instances when the injuries are severe enough to warrant the label.

Other sports also present the opportunity for severe trauma. These sports include hiking, skiing, rafting, and snowboarding (60). Each sport presents a specific risk. For example, skiing and snowboarding accidents often involve significant falls and/or crashes involving trees or other objects. These accidents typically result in severe head trauma and broken or fractures bones (57). Hiking accidents typically involve falls, which have been discussed above. However, hiking accidents may also cause other injuries such as severe abrasions and hypothermia. Rafting accidents can cause severe trauma to both internal and external organs (60).

While they are not commonly considered sport related injuries, injuries caused by recreational vehicles are included in this category. This includes all terrain vehicles (ATV’s), snowmobiles and four wheelers. These vehicles are not
included in the section on motor vehicle related accidents, as they are not considered motor vehicles. Therefore, they are included in this section as recreational vehicles are often considered sporting vehicles.

Recreational vehicles are responsible for a significant number of the trauma cases each year. Regardless of the type of recreational vehicle, the driver and passenger travel at high speeds in unsafe conditions (snow, mud, trails), with minimal protective gear (61). Most recreational vehicle accidents cause the driver and passenger to be thrown some distance from the vehicle and often involve impact with another object (tree, ground, vehicle, building). Therefore, the injuries sustained during recreational vehicle accidents are quite severe. Typical injuries include head trauma, broken bones and fractures, internal organ damage, and external abrasions and lacerations (58).

The primary causes of polytrauma have been listed above. However, polytrauma can occur as the result of any type of accident, as long as it is severe enough to produce multiple injuries, with at least one of them being life threatening. In some extreme cases, polytrauma can be the result of violent attacks such as domestic violence or bullying. In other instances, when an individual survives an event that would otherwise be fatal, such as a parachuting accident or a plane crash, polytrauma is likely to occur. Regardless of the event that causes the trauma, it is important to understand how the trauma affects the body so that appropriate and immediate treatment can be initiated.

**COMMON INJURIES**

Some of the causes of polytrauma listed above, such as military explosions, produce consistent injury patterns that are specific to the device. However, in most other types of trauma inducing accidents, there is not a consistent injury pattern. The type of injury is dependent upon a number of factors. While injuries
differ depending on the type of accident and situational factors, there are still some commonalities. In fact, regardless of the cause of polytrauma, there are a number of common injuries that individuals can experience. These injuries tend to be severe and is often life threatening (62). It is necessary to understand the commonalities between causes of trauma so that treatment can be consistent.

An individual might sustain a traumatic brain injury from contact with an explosive device during contact or as the result of a fall during a hiking expedition. While the accidents that cause the head trauma are different, the injury is the same and will require the same type of treatment. Therefore, it is important to understand which injuries are common to polytrauma.

**Traumatic Brain Injury**

Traumatic Brain Injury (TBI) is one of the most common trauma related injuries as it can occur as the result of almost all of the types of accidents listed above. In fact, traumatic brain injury might be the most common trauma related injury, especially in military polytrauma cases. According to the Center for Disease Control, approximately 1.7 million traumatic brain injuries occur each year (63). Many of these injuries occur along with other injuries.

Traumatic brain injury is commonly referred to as either TBI, acquired brain injury, or head injury (64). It is caused by a sudden trauma to the head that causes damage to the brain. Depending on how the trauma occurs, the resulting damage may be focal, which means it is confined to a single area; or it can be diffuse, which involves injury to more than one area of the brain (65). Traumatic brain injury results from either a closed head injury or from a penetrating head injury. The head hitting an object, which results in the brain moving within the skull, causes closed head injuries. The object causes trauma to the head, but it does not penetrate the skin. A penetrating injury occurs by an object piercing the skull and entering the brain tissue (63).
Traumatic brain injury is the direct result of a blow to the head. However, not all forces to the head cause traumatic brain injury. Depending on a number of factors, such as the level of impact and the type of object, the severity of the injury may range from non-existent to severe (66). In instances where the force actually causes some level of trauma, the injury will range from mild to severe (63). Mild injuries typically cause a minor, or brief, change in mental status. Mild injuries may result in a temporary loss of consciousness, but there will be no long term adverse affects (67). Severe injuries can result in full, extended loss of consciousness. They may also cause short or long-term amnesia (68). Throughout all levels of injury, TBI produces a range of functional and sensory changes. These changes impact the patient’s movement, thinking, sensation, language, and emotions (63).

Many of the symptoms of traumatic brain injury develop over time and may not appear for a number of days or weeks. In some rare cases, the symptoms may not appear for months (69). Many patients with mild traumatic brain injury will recover within a number of weeks or months, although some symptoms may persist for longer (65). In patients who experience moderate to severe traumatic brain injury, the recovery time is greater. In fact, many moderate to severe TBI patients never fully recover (70). Many TBI symptoms are life long complications. According to the Center for Disease Control, approximately 5.3 million Americans are living with a TBI-related disability (63).

A concussion is the most common and most mild form of traumatic brain injury. The Center for Disease Control defines a concussion as “a type of traumatic brain injury, or TBI, caused by a bump, blow, or jolt to the head that can change the way your brain normally works. Concussions can also occur from a fall or a blow to the body that causes the head and brain to move quickly back and forth (71).” However, the term is commonly used to identify a mild injury to the head or brain. Concussions can range in severity and some require extensive medical...
treatment. If untreated, some concussions can cause more significant problems (72).

Most individuals will recover fully from a concussion over a short period of time. However, some individuals require more recovery time. For these individuals, recovery can take a number of days, weeks or even months (67). In addition, some individuals may experience severe symptoms as a result of a concussion that indicate that the patient is at risk of developing long-term complications (56). It is important that providers recognize the different symptoms of concussions so that they are able to differentiate between common symptoms and those that indicate a more significant problem. Typical concussion symptoms are identified using the following four categories:

- Thinking/Remembering
- Physical
- Emotional/Mood
- Sleep

Using the categories listed above, the following table provides an overview of standard concussion symptoms:

<table>
<thead>
<tr>
<th>Thinking/Remembering</th>
<th>Physical</th>
<th>Emotional/Mood</th>
<th>Sleep</th>
</tr>
</thead>
<tbody>
<tr>
<td>Difficulty thinking clearly</td>
<td>Headache; Fuzzy or blurry vision</td>
<td>Irritability</td>
<td>Sleeping more than usual</td>
</tr>
<tr>
<td>Feeling slowed down</td>
<td>Nausea or vomiting (early on); Dizziness</td>
<td>Sadness</td>
<td>Sleep less than usual</td>
</tr>
<tr>
<td>Difficulty concentrating</td>
<td>Sensitivity to noise or light; Balance problems</td>
<td>More emotional</td>
<td>Trouble falling asleep</td>
</tr>
<tr>
<td>Difficulty remembering new information</td>
<td>Feeling tired, having no energy</td>
<td>Nervousness or anxiety</td>
<td></td>
</tr>
</tbody>
</table>

(72)
The symptoms listed above are common concussion symptoms. However, there are some symptoms that are considered a red flag to providers and warrant immediate attention.

According to the Center for Disease Control, the following warning signs should be taken seriously and should be treated immediately:

**Danger Signs in Adults**
- Headache that gets worse and does not go away.
- Weakness, numbness or decreased coordination.
- Repeated vomiting or nausea.
- Slurred speech.

Emergency treatment should be sought immediately if the patient shows any of the following signs:
- Looks very drowsy or cannot be awakened.
- Has one pupil (the black part in the middle of the eye) larger than the other.
- Has convulsions or seizures.
- Cannot recognize people or places.
- Is getting more and more confused, restless, or agitated.
- Has unusual behavior.
- Loses consciousness (a brief loss of consciousness should be taken seriously and the person should be carefully monitored).

**Danger Signs in Children**
- Any of the danger signs for adults listed above.
- Will not stop crying and cannot be consoled.
- Will not nurse or eat (72)
Although mild traumatic brain injury can occur during instances of polytrauma, it is more common for patients with polytrauma to experience moderate to severe traumatic brain injury (56). There are various types of traumatic brain injury. While many of the injuries to the brain can be mild to moderate, other injuries are more severe. The following are descriptions of the more severe types of brain injury:

**Skull Fracture**
One of the most common severe injuries is the skull fracture. Although skulls serve as the first line of defense in protecting the brain, they are actually quite prone to injury. There are two distinct types of skull fracture:
- **Depressed Skull Fracture** - This type of fracture is caused by pieces of the broken skull pressing into the brain tissue
- **Penetrating Skull Fracture** - This type of skull fracture is caused by something piercing the skull (e.g. bullet, knife, etc.). The object produces a distinct injury to the brain tissue, which is localized (73).

**Contusion**
A contusion is bruising of the brain tissue. This type of injury can be the result of a skull fracture or when the brain shakes back and forth within the skull (contrecoup) (56).

**Diffuse Axonal Injury**
This injury, also known as shearing, is caused by contrecoup and is characterized by damage to neurons and the subsequent loss of connections among them. Once this occurs, there is the potential for the breakdown of communication among all neurons in the brain (70).

**Hematoma**
A hematoma is the result of damage to one of the major blood vessels in the head. There are three types of hematomas that affect the brain:
- Epidural Hematoma – the bleeding that occurs between the skull and the dura identifies this type of hematoma.
- Subdural Hematoma – In this type of hematoma, the blood is confined between the dura and the arachnoid membrane.
- Intracerebral Hematoma – this type of hematoma is characterized by bleeding that occurs within the brain itself (63).

Anoxia
With anoxia, injury occurs as the result of a complete lack of oxygen to the organ’s tissues. While there may still be blood flow to the tissues, there is no oxygen present (68).

Hypoxia
Similar to anoxia, hypoxia is the result of lack of oxygen to the organ’s tissues. However, with hypoxia, there is minimal oxygen present (70).

Causes of TBI
A majority of traumatic brain injuries cases (approximately half) occur as the result of transportation accidents, which includes automobiles, motorcycles, bicycles, and pedestrian accidents. These accidents are the major cause of TBI in people under age 75 (64). For those individuals that are 75 years and older, falls cause the majority of TBIs (52). Approximately 20% of TBIs are due to violence, such as firearm assaults and child abuse, and about 3% are due to sports injuries (56).

The cause of the TBI plays a role in determining the patient’s outcome. For example, approximately 91% of firearm TBIs (two-thirds of which may be suicidal in intent) result in death, while only 11% of TBIs from falls result in death (56). Civilians and military personnel in combat zones are also at increased risk for TBIs. The leading causes of such TBI are bullets, fragments and blasts, falls,
motor vehicle-traffic crashes, and assaults. Blasts are a leading cause of TBI for active-duty military personnel in war zones (74).

**Assessment and Treatment**

Assessment and treatment of a traumatic brain injury should begin as soon as possible. Therefore, emergency personnel are often the first individuals who assess and treat traumatic brain injury (70). Typically, treatment begins as soon as emergency responders arrive on the scene or as soon as an individual arrives at the emergency room. Initial brain damage that is caused by trauma cannot be reversed. So, initial treatment involves stabilizing the patient and administering treatment that will prevent further damage (65).

Due to the diverse causes of traumatic brain injury and the differing needs of patients, initial contact with the patient involves an assessment of the cause of the injury and a screening to determine the extent of the injuries (65). This is important because the mechanism of injury will determine the type of treatment needed. For example, blast trauma related traumatic brain injury is more complex than other forms of traumatic brain injury (75). Due to the complexity of blast related traumatic brain injury, the assessment and treatment can be difficult to administer and determine. Therefore, in combat, it is more common to evaluate all service members who have been exposed to a blast and identify those that present symptoms of traumatic brain injury (75). However, in civilian instances of traumatic brain injury, it is more common to assess each patient individually based on the symptoms present as non blast related causes of traumatic brain injury tend to be less complicated (65).

Prior to conducting a full assessment of an individual who is suspected of having a traumatic brain injury, the primary concern is ensuring that the patient is stabilized and that any further injury is prevented. During the initial stage of contact, medical personnel are primarily concerned with ensuring that the patient has a proper supply of oxygen to the brain and the rest of the body (70). Another
priority is to maintain an adequate blood flow while controlling blood pressure. This will help stabilize the patient while minimizing further damage to the brain (65).

Once a patient is stabilized, medical personnel will assess the patient and determine the extent of the injury. Primary assessment includes measuring vital signs and reflexes, as well as administering a thorough neurological exam. The initial exam includes checking the patient’s temperature, blood pressure, pulse, breathing rate, pupil size and response to light (65). After the vital signs and basic neurologic functions are assessed, the emergency medical provider will assess the patient’s level of consciousness and neurologic functioning. This assessment is done using the Glasgow Coma Scale, which is a standardized, 15-point test that measures neurologic functioning using three assessments: eye opening, best verbal response, and best motor response. These measures are used to determine the severity of the brain injury (63).

The Center for Disease Control provides the following guidelines for the Glasgow Coma Scale. Medical responders should use the scale to assess the level of severity of trauma.

**Glasgow Coma Scale:**

**Eye Opening Response**
- Spontaneous--open with blinking at baseline - 4 points
- To verbal stimuli, command, speech - 3 points
- To pain only (not applied to face) - 2 points
- No response - 1 point

**Verbal Response**
- Oriented - 5 points
- Confused conversation, but able to answer questions - 4 points
• Inappropriate words - 3 points
• Incomprehensible speech - 2 points
• No response - 1 point

Motor Response
• Obeys commands for movement - 6 points
• Purposeful movement to painful stimulus - 5 points
• Withdrawing responses to pain - 4 points
• Flexion in response to pain (decorticate posturing) - 3 points
• Extension response in response to pain (decerebrate posturing) - 2 points
• No response - 1 point

Categorization:
• Coma:
  o No eye opening, no ability to follow commands, no word verbalizations (3-8)
• Head Injury Classification:
  o Severe Head Injury ---- GCS score of 8 or less
  o Moderate Head Injury ---- GCS score of 9 to 12
  o Mild Head Injury ---- GCS score of 13 to 15

Disclaimer: Based on motor responsiveness, verbal performance, and eye opening to appropriate stimuli, the Glasgow Coma Scale was designed and should be used to assess the depth and duration coma and impaired consciousness. This scale helps to gauge the impact of a wide variety of conditions such as acute brain damage due to traumatic and/or vascular injuries or infections, metabolic disorders (e.g., hepatic or renal failure, hypoglycemia, diabetic ketosis), etc. (76).

After the Glasgow Coma Scale is administered, further testing is conducted to determine the level of damage and the severity of the injury. Imaging tests are
used to assist with the diagnosis of the patient as well as make a determination about the prognosis of the patient (65). Skull and neck X-rays are used to check for bone fractures and spinal instability in patients with mild to moderate injuries (77). In patients with mild traumatic brain injury, a diffusion tensor imaging is sometimes used. This device can reliably detect and track brain abnormalities and is sensitive enough to be used on patients with mild injury (67). In some cases, a magnetoencephalography may be used to obtain further information regarding a mild case of traumatic brain injury (65).

Additional diagnostic imaging is used in cases of moderate to severe traumatic brain injury. In these instances, patients will be assessed using a computed tomography (CT) scan. This scan creates cross sectional X-ray images of the head and brain and is used to identify any bone fractures that might be present in the skull. The CT scan also indicates if there is the presence of hemorrhage, hematomas, contusions, brain tissue swelling, and tumors (70).

Once the initial assessment is complete, additional imaging may be conducted. In these instances a magnetic resonance imaging (MRI) is often used to determine if there is additional damage beyond the scope of the initial assessment. The MRI is used to determine if there have been any subtle changes in the brain tissue and are used when more detail is needed than standard x rays can provide (65). MRI’s are not used during the initial emergency assessment as they require a significant amount of time and are not always available during the initial assessment (70). However, an MRI is an important diagnostic tool and should be used when appropriate and available.

The initial assessment and diagnostic imaging is used to determine the level of severity of the injury and to determine any specific complications. Once this information is obtained, and the patient is stabilized, medical personnel can begin to treat the specific injuries. Treatment is individualized based on the specific injuries and the severity of the damage.
In some instances, a patient with traumatic brain injury may require initial surgical interventions. These surgical interventions are conducted immediately following the initial assessment and treatment stage, as they are used as immediate treatment to minimize some of the initial complications that are most threatening to the success of the patient (64). When a patient requires an initial surgical intervention, he or she is typically admitted to the intensive care unit for further treatment and monitoring. Initial surgical interventions are used to remove or repair hematomas and contusions (70).

In many instances, a patient will experience swelling in the brain. When this occurs, fluids accumulate within the brain and pressure begins to build. This causes additional swelling and disruptions to the fluid balance (63). With other injuries, swelling and fluid accumulation is normal and poses little risk. However, when this occurs within the brain, it can be extremely dangerous. The skull limits the space for expansion, so the brain is unable to expand. Therefore, the accumulation of fluid causes unnecessary pressure on the brain, which is known as increased intracranial pressure (ICP) (56).

When a patient presents with swelling in the brain, it is necessary to monitor the swelling to ensure that it does not cause additional damage. This is accomplished using a probe or catheter (70). The instrument is inserted into the skull and is placed at the subarachnoid level to ensure accurate measurements. Once the instrument is properly placed, it is connected to a monitor that displays information regarding the patient’s ICP. This information is closely monitored so that action can be taken if the ICP reaches an alarming level (65). If this occurs, the patient may have to undergo a ventriculostomy. This procedure is used to drain cerebrospinal fluid as a way to reduce pressure on the brain. In some instances, pharmacological agents may be used to decrease ICP. These drugs include mannitol and barbituates (70).
TBI Complications

Traumatic brain injuries can cause a number of complications that may occur during the onset of the injury, as well as after the injury has been treated and resolved. In some instances, these complications may be mild and easily treatable and manageable. In other instances, these complications can pose a significant threat to the individual. Some complications can be life threatening, while others may cause long-term disability (56).

A traumatic brain injury can cause some significant initial complications within the following categories:

- Arousal
- Consciousness
- Awareness
- Alertness
- Responsiveness (66)

Within these five categories, there are five abnormal states of consciousness that can occur in a TBI patient. These include stupor, coma, persistent vegetative state, locked-in syndrome, and brain death (63).

- Stupor:
  When a patient experiences a stupor, he or she is often unresponsive but is able to be aroused, if only briefly, by a strong stimulus (70).

- Coma:
  During a coma, a patient is completely unconscious and cannot be aroused. The patient is also unresponsive and unaware of his or her surroundings. Patients will not respond to external stimuli and do not experience sleep-wake cycles. A coma is typically the result of severe trauma to the brain, and is most common with injuries to the cerebral hemispheres of the upper brain and the lower brain or brainstem. In most instances, a coma will only last for a few days or a few weeks. However,
in some extreme situations, a patient may progress to a vegetative state (76).

- **Vegetative State:**
  When a patient is in a vegetative state, he or she is completely unaware of the surroundings. However, unlike with a coma, patients in a vegetative state continue to have a sleep-wake cycle. In addition, patients may experience periods of alertness (65). Patients in a vegetative state will often open their eyes and show other signs of movement and function, which may include groaning and some reflex responses (70). In many instances, a vegetative state is the result of trauma to the cerebral hemispheres with the absence of injury to the lower brain and brainstem (66). Most patients will only remain in a vegetative state for a few weeks, but some may progress to a persistent vegetative state, which is defined as longer than thirty days (70). Once a patient has been in a vegetative state for a year, the chances of recovery are extremely low (66).

- **Locked-In Syndrome:**
  With Locked-In Syndrome, the patient is unable to move or communicate normally as the result of paralysis of the body. However, the patient is fully aware and awake (63). Locked-In Syndrome is caused by damage to areas in the lower brain and brainstem, but not by damage to the upper brain (66). Typically, patients use movements and eye blinking to communicate. Ultimately, most patients do not gain their motor control back once they are in a locked-in state (70).

- **Brain Death:**
  Brain death is a newer diagnosis that has occurred due to the development of assistive devices that artificially maintain blood flow and breathing (70). Brain death is defined as a lack of measurable brain function. This is typically caused by injuries to the cerebral hemispheres
and brainstem (66). There is also a loss of integrated activity within specific areas of the brain (70). This condition is irreversible. If a patient does not remain on assistive devices, he or she will experience immediate cardiac arrest and will stop breathing (56).

The various unconscious states listed above are easy to diagnose as the result of advancements in imaging and other technologies. Using these new technologies, practitioners can identify the area of the brain affected and diagnose the patient based on the level of activity present in different regions of the brain (65). Most commonly, doctors use CT and MRI to identify the affected areas of the brain. However, other diagnostic imaging tools such as cerebral angiography, electroencephalography (EEG), transcranial Doppler, ultrasound, and single photon emission computed tomography (SPECT) might be used (64).

The aforementioned conditions are complications that are specific to traumatic brain injury. However, there are also conditions that can occur immediately after a traumatic brain injury that are not specific to TBI, but that occur as a direct result of the injury. These complications increase in prevalence in direct correlation to the severity of the injury.

Complications of TBI include:

- Immediate seizures
- Hydrocephalus or posttraumatic ventricular enlargement
- CSF leaks
- Infections
- Vascular injuries
- Cranial nerve injuries
- Pain
- Bed sores
- Multiple organ system failure in unconscious patients
Seizures:
It is common for approximately 25% of patients with brain contusions or hematomas to experience seizures. In addition, approximately 50% of patients with penetrating head injuries will experience seizures (78). In these patients, seizures typically occur within the first 24 hours of the injury (79). While some patients who experience immediate seizures will have an increased risk of developing seizures that occur within one of the injury, there is no risk of the patient developing posttraumatic epilepsy. Typically, patients who experience immediate or early seizures are treated with anticonvulsants if the seizures are persistent and recurring (78).

Hydrocephalus and Posttraumatic Ventricular Enlargement:
Hydrocephalus or posttraumatic ventricular enlargement is a condition that is caused by the accumulation of cerebrospinal fluid in the brain. This excess fluid causes dilation of the cerebral ventricles and an increase in ICP (80). This condition is common during the acute stage of traumatic brain injury, but it can also occur during later stages (64). It is most common within the first year of the injury (56). It is characterized by worsening neurologic outcome, behavioral changes, incontinence, ataxia, and impaired consciousness (80). This condition typically develops as a result of meningitis, subarachnoid hemorrhage, intracranial hematoma, or various other injuries that have the potential to produce pressure (70). Typical treatment involves shunting and draining the fluid (65).

CSF Leaks:
As the result of a skull fracture, a patient may experience tears in the membranes that cover the brain. These tears can result in leaks of cerebral spinal fluid. When a patient experiences a tear between the dura and the arachnoid membrane, which is referred to as a CSF fistula, cerebral spinal fluid will often leak out of the subarachnoidal space into the subdural space. This type of leaking is referred to as a subdural hygromea (81). In some instances, cerebrospinal fluid may leak out of the nose and ears (70). When a patient has tears that
cause CSF to leak from the brain cavity, they are at an increased risk of developing infections such as meningitis, which is caused by air and bacteria entering the cavity (81). Patients are also at risk of developing pneumocephalus form air entering the intracranial cavity and becoming trapped in the subarachnoid space (81).

Infections:
Individuals with traumatic brain injury are prone to a number of infections that can occur within the intracranial cavity. Depending on the type of injury, infections can occur in a variety of locations in the brain, including the dura, below the dura, below the arachnoid, and within the space of the brain (64). The majority of infections will develop within a few weeks of the trauma. They can result from penetrating injuries or from skull fractures. Patients are typically treated with antibiotics. However, surgery may occasionally be used to remove sections of the infected tissue (70).

Vascular Injuries:
Traumatic brain injury patients are especially prone to vascular injuries due to the damage caused to the head and/or brain. While damage to small blood vessels rarely has a significant impact on the patient, damage to the large blood vessels can result in severe complications. For instance, damage to a major artery may result in a stroke due to bleeding from the artery or as a result of the formation of a clot (56).

Common types of vascular injuries include:
- Hemorrhagic stroke – bleeding directly from the artery
- Ischemic stroke – blocked blood flow to the brain
- Thrombus or thrombosis – the formation of a clot at the site of the injury
- Vasospasm – an exaggerated, persistent contraction of the walls of the blood vessel.
- Aneurysms – blood filled sacs caused by stretching of an artery of blood vessel (82)

Patients with the above conditions may experience headaches, vomiting, partial paralysis (often on one side of the body) and semi-consciousness. These symptoms often appear several days after the injury (64). Depending on the specific complication, different treatments will be used. For example, anticoagulants are often used to treat ischemic strokes. However, surgery is typically used to treat hemorrhagic strokes (70).

Cranial Nerve Injuries:
Patients will often experience cranial nerve injuries as the result of skull fractures, especially when the fracture occurs at the base of the skull (83). These cranial nerve injuries often result in compressive cranial neuropathies. The brainstem contains twelve cranial nerves, with nine of them projecting out toward the head and face. Therefore, cranial nerve damage often results in partial paralysis of facial muscles (84).

The conditions included above occur immediately following the onset of a traumatic brain injury. Therefore, they are often identified and treated during the initial stage of injury (65). In addition to injuries that occur during the initial stage of injury, there are other complications that will develop over time and that will typically last throughout the individual’s lifetime, or at least for a significant period of time (66). These complications are considered TBI related disabilities.

TBI related disabilities vary depending on the location of the injury, the severity of the injury and the age and general health of the patient. The most common types of TBI related disabilities affect the following areas:
- cognition (thinking, memory, and reasoning)
- sensory processing (sight, hearing, touch, taste, and smell)
- communication (expression and understanding)
• behavior or mental health (depression, anxiety, personality changes, aggression, acting out, and social inappropriateness).

It is quite common for TBI patients to develop a range of symptoms and complications as a result of the injury. In fact, approximately 40% of all TBI patients develop post concussion syndrome (PCS), which is defined simply as a collection of symptoms, within days or weeks of suffering an injury (71). PCS is common in all TBI patients, not just those who have experienced a concussion or loss of consciousness. In fact, a number of patients who are being treated for mild TBI are diagnosed with PCS. The following symptoms are common in patients with PCS:

- Headache
- Dizziness
- Vertigo (a sensation of spinning around or of objects spinning around the patient) Memory problems
- Trouble concentrating
- Sleeping problems
- Restlessness
- Irritability
- Apathy
- Depression
- Anxiety (85)

These symptoms may last for a few weeks after the head injury. Typical treatment involves the use of medicines and therapy to reduce the impact of the symptoms and help the patient cope (86).

Cognitive Impairments

It is common for patients with traumatic brain injury to experience cognitive disabilities, especially if they have lost consciousness. In many patients, the impairments include a loss of higher-level mental skills (87). Of the different cognitive impairments, memory loss is the most common, with patients...
experiencing the loss of specific memories and the inability to form or store new memories. In some instances, patients may develop posttraumatic amnesia. There are two types of posttraumatic amnesia:

- Anterograde – impaired memory of events that happened after the TBI
- Retrograde – impaired memory of events that happened before the TBI

It is common for patients with cognitive impairments to become confused easily or to have problems with distraction. These patients will typically experience difficulty concentrating and focusing their attention. Some patients may also experience problems with higher-level functions, which includes planning, organizing, abstract reasoning, problem solving, and making judgments (87).

Patients experience the greatest recovery during the first six months, after which the recovery becomes more gradual. Cognitive impairments are more common in patients with moderate or severe TBI (70).

Sensory Problems:

Sensory impairments are common in TBI patients. The most common form of sensory impairment is with vision. It is common for TBI patients to experience difficulty registering what they are seeing or recognizing various objects (89). TBI patients are also prone to problems with hand eye coordination. Due to these impairments, TBI patients often experience difficulty maneuvering through spaces and often bump into objects or drop them (90).

Sensory impairments produce a general instability in TBI patients. As a result, many TBI patients are unable to operate motor vehicle or complex machinery (89). Many of these sensory issues cannot be treated and remain with the patient indefinitely. However, in some instances, optometric vision therapy has produced good results in patients with oculomotor dysfunctions (91).
While vision impairments are the most common form of sensory impairment in TBI patients, some patients will also develop problems with hearing, smell, taste, or touch. These impairments are the result of damage to the areas of the brain that controls these senses. These conditions are difficult to treat (89).

Language and Communication Problems:
Many TBI patients experience language and communication problems. Some patients only experience difficulties with subtle aspects of communication, such as body language and emotional, nonverbal signals (92). However, others will actually experience difficulty understanding and producing spoken and written language. This type of impairment is called aphasia (93).

The following is a list of the different forms of aphasia:

- Broca’s Aphasia (nonfluent/motor) – difficulty recalling words and/or speaking in complete sentences. Characterized by broken phrases and frequent pauses. Patients often experience extreme frustration.

- Wernicke’s Aphasia (fluent/sensory) – Patients display little meaning in their speech, but typically speak in complete sentences and use correct grammar. Characterized by the use of flowing gibberish and sentences that include nonessential and invented words. Patients are often unaware that they are not making sense and express frustration when others do not understand them.

- Global Aphasia – extensive damage to the portions of the brain responsible for language. Characterized by severe communication disabilities (92).

In some instances, TBI patients may experience difficulties with spoken language as a result of damage to the section of the brain that controls the speech muscles. This disorder is called dysarthria, and it affects patients differently than other impairments. With dysarthria, the patient is able to understand and think of appropriate words/language. However, the patient is unable to speak the words
because of damage to the speech muscles (93). Therefore, speech may be
slurred and garbled. Some patients experience difficulty with intonation or
inflection. This is called prosodic dysfunction (92).

Emotional and Behavioral Problems:
Many TBI patients experience emotional and behavioral difficulties, which are
often classified as general psychiatric issues. It is common for a TBI patient to
exhibit personality changes and behavioral issues. The following is a list of the
common psychiatric problems experienced by TBI patients:

- Depression
- Apathy
- Anxiety
- Irritability
- Anger
- Paranoia
- Confusion
- Frustration
- Agitation
- Insomnia or other sleep problems
- Mood swings

Typically, behavioral problems include the following:

- aggression and violence
- impulsivity
- disinhibition
- acting out
- noncompliance
- social inappropriateness
- emotional outbursts
- childish behavior
- impaired self-control
- impaired self-awareness
- inability to take responsibility or accept criticism
- egocentrism
- inappropriate sexual activity
- alcohol or drug abuse/addiction (94)

In some instances, the personality issues may be severe enough to warrant a diagnosis of borderline personality disorder (90). Other TBI patients may experience developmental stagnation. When this occurs, the patient fails to mature emotionally, socially, or psychologically after the trauma (94). This is especially problematic for children and young adults who suffer from a TBI.

Typical treatment for the various emotional and behavioral problems includes medication and therapy (65).

Long-term Problems:
In addition to the immediate post-injury complications, other long-term problems can develop after a TBI. These include Parkinson’s disease and other motor problems, Alzheimer’s disease, chronic traumatic encephalopathy, and posttraumatic dementia.

Parkinson's Disease:
In some patients, Parkinson’s disease may develop years after TBI as a result of damage to the basal ganglia. Symptoms of Parkinson’s disease include:
- tremor or trembling
- rigidity or stiffness
- slow movement (bradykinesia)
- inability to move (akinesia)
- shuffling walk
- stooped posture
Parkinson’s Disease is a rare complication of TBI, but it can occur. Other movement disorders that may develop after TBI include tremor, ataxia (uncoordinated muscle movements), and myoclonus (shock-like contractions of muscles) (94).

Alzheimer’s Disease:
Alzheimer’s disease (AD) is defined as a progressive, neurodegenerative disease characterized by dementia, memory loss, and deteriorating cognitive abilities. According to recent research, there is an association between head injury in early adulthood and the development of AD later in life. The risk of developing AD later in life is increased in direct correlation to the severity of the head injury (95).

Chronic Traumatic Encephalopathy and Amyotrophic Lateral Sclerosis:
There is evidence that TBI contributes to the incidence of nerve degenerative diseases such as amyotrophic lateral sclerosis (ALS) and chronic traumatic encephalopathy (CTE). In fact, there is pathological evidence that there is a direct correlation between repeated blows to the head and the long-term development of these diseases (96).

Posttraumatic Dementia:
Posttraumatic dementia is characterized by symptoms of both dementia and Parkinson’s and is caused by a single, severe TBI that results in a coma (94).

Long Term Treatment for Traumatic Brain Injury:
Many individuals experience long-term complications and disabilities as the result of traumatic brain injury (97). Therefore, long-term treatment is often needed beyond the emergency treatment that is provided initially. Initial treatment for patients with moderate to severe traumatic brain injury is focused on stabilizing the patient and is often done within the emergency department or intensive care
unit (65). Once the patient is stabilized, further treatment may be required depending on the type and severity of the injury.

Most long-term treatment involves rehabilitation, as the goal is to have the patient regain the appropriate neurologic functions. This component of treatment is often conducted in a subacute unit of the hospital or in an independent rehabilitation center (70). In addition, some long-term treatment will be conducted through outpatient services (65). Treatment at this stage is diverse and is tailored to the specific recovery needs of the patient.

Most long-term treatment includes physical therapy, occupational therapy, speech and language therapy, psychiatric care, psychological services, social support and life skill development, and physiatry (90). The specific rehabilitative program will utilize the services of experts in the above areas to develop a comprehensive program that addresses the specific treatment needs of the program. Initial treatment will most likely be extensive, with longer-term treatment being less frequent (97). As the patient regains the appropriate skills, treatment will be reevaluated and modified to continue to meet the needs of the patient (90).

The goal of long-term treatment is to bring the patient to a level of functioning that enables him or her to live independently and integrate with society. When patients experience a long term or permanent disability as the result of the traumatic brain injury, the rehabilitation team will provide treatment and therapy that focuses on adapting to the disability and developing new skills that will enable the patient to function within the constraints of the disability (97). Long-term rehabilitation will typically be conducted in a variety of settings, including hospital outpatient programs, inpatient rehabilitation centers, day treatment programs, hospital outpatient programs and independent living centers. The specific setting will be determined based on the rehabilitation needs of the patient and the specific services available in the geographic area (87).
Due to the nature of polytrauma, traumatic brain injury treatment will be conducted in conjunction with treatment for other injuries and conditions. During the initial stages of treatment, medical practitioners will collaborate to address the various treatment needs of the patient so that all injuries and conditions receive the proper care and treatment (65). Once the patient has been stabilized and acute injuries have been treated, the long-term treatment plan will be developed and will include treatment for all trauma conditions, including traumatic brain injury.

**Limb Loss**

Limb loss, which is defined as the loss of part of the arm or the leg, can be a common injury during polytrauma situations as many of the accidents that cause polytrauma are severely damaging to the individual’s body. Limb loss can occur directly during the trauma (e.g. limbs being blown off during an explosive accident), or they can occur through amputation after the accident as a treatment measure. According to the Center for Disease Control, approximately two million people in the United States are living with limb loss (98).

When limbs are amputated in response to specific injuries sustained during an accident, there are specific amputation locations, which are called amputation levels. The treatment team will determine where to amputate the limb based on the severity of the injury and the areas affected (99). The following is a list of the different amputation levels (30):

- Partial Foot or Toe(s) (incl. Symes)
- Below Knee (incl. Rotationplasty)
- Above Knee (incl. Knee Disarticulation)
- Hip Disarticulation or Hemipelvectomy
- Bilateral Lower Limb Loss
- Partial Hand or Finger(s)
- Below Elbow (incl. Wrist Disarticulation)
- Above Elbow (incl. Elbow Disarticulation)
- Shoulder Disarticulation or Forequarter
- Bilateral Upper Limb Loss

When limbs are blown off during an explosive accident or are torn from the body as part of another type of accident, it is often necessary to remove additional parts of the limb so that the loss occurs within one of the pre-determined amputation levels (100). Limb loss and damage that is a direct result of an explosion or accident is typically very uneven and includes an abundance of damaged, unsalvageable tissue, bone and ligaments. Therefore, the treatment team will most likely need to “clean up” the area and remove the additional damaged tissue, bone and ligaments (101). This ensures a smooth amputation and ensures that the loss site is clean and can be fitted for a prosthetic device (if one is deemed necessary and/or appropriate) (102).

In many instances, a body part will sustain significant damage as a result of the accident. However, the limb will not be detached from the body in any way. This often occurs when significant tissue damage occurs (98). In these instances, the emergency treatment team either provides treatment that will salvage the extremity, or they will have to amputate the extremity (103). This decision is not made lightly. Salvaging the limb is always the preferred option if the limb function can be restored or maintained, or if the severity of the injury will not cause further damage to the patient. In many instances, the tissue damage is so severe that the limb cannot be salvaged (100).

There are a number of assessment tools that emergency providers can use to determine the severity of the injury to the extremity and the potential for repair and restoration. The data obtained from these assessments is used to make a final determination regarding amputation. The following are the available assessment tool and scoring systems:
- Predictive Salvage Index (PSI)
• Mangled Extremity Severity Score (MESS)
• Limb Salvage Index (LSI)
• Nerve Injury, Ischemia, Soft-Tissue Injury, Skeletal Injury, Shock, and Age (NISSSA) Score
• Hannover Fracture Scale-98 (HFS-98)

Each scoring system uses different criteria to determine extremity damage and viability.

Predictive Salvage Index

Overview:
The Predictive Salvage Index (PSI) is used to evaluate severity of a lower extremity that has undergone trauma with orthopedic and vascular injuries.

Parameters include:
1. level of arterial injury
2. degree of bone injury
3. degree of muscle injury
4. interval from injury until arrival in the operating room

<table>
<thead>
<tr>
<th>Tissue Injury</th>
<th>Findings</th>
<th>Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>bone</td>
<td>transverse fracture with possible butterfly component; simple oblique fracture; fracture dislocation of joint</td>
<td>mild</td>
</tr>
<tr>
<td></td>
<td>comminuted fracture over 2-5 cm</td>
<td>moderate</td>
</tr>
<tr>
<td></td>
<td>comminuted fracture &gt;5 cm; or segmental loss</td>
<td>severe</td>
</tr>
<tr>
<td>muscle</td>
<td>laceration of one or more muscles in a single compartment; no significant crush component</td>
<td>mild</td>
</tr>
<tr>
<td></td>
<td>laceration of one or more muscles in 2 compartments; crush-revulsion component</td>
<td>moderate</td>
</tr>
<tr>
<td></td>
<td>laceration of one or more muscles in 3 or 4 compartments</td>
<td>severe</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Findings</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>level of arterial injury</td>
<td>suprapopliteal</td>
<td>1</td>
</tr>
</tbody>
</table>
### Predictive Salvage Index

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>popliteal</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>infrapopliteal</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>degree of bone injury</td>
<td>mild</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>moderate</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>severe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>degree of muscle injury</td>
<td>mild</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>moderate</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>severe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>interval before surgery</td>
<td>&lt;6 hours</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6−12</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Predictive Salvage Index = SUM (points for all 4 parameters)

**Interpretation:**

Minimum score: 3 (based on the point assignments; if no vascular, bone or muscle injury then the score could reach 1, but then it would not be a seriously injured limb)

Maximum score: 13

The higher the score the worse the chances for a successful limb salvage (104).

### Mangled Extremity Severity Score

**Overview:**

The Mangled Extremity Severity Score can be used to evaluate patients with lower extremity trauma with vascular compromise. It can help to decide whether to attempt limb salvage or to perform amputation.

**Parameters include:**

1. extent of skeletal and soft tissue injury
2. patient’s blood pressure
3. duration and extent of limb hypoperfusion
4. age of patient
<table>
<thead>
<tr>
<th>skeletal and soft tissue injury</th>
<th>low energy (stab wounds, simple closed fractures, small caliber gunshot wounds)</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>medium energy (open or multiple level fractures, dislocations, moderate crush injuries)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>high energy (shotgun blast at close range, high velocity gunshot wound)</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>massive crush injury (logging, railroad or oil rig accidents)</td>
<td>4</td>
</tr>
<tr>
<td>shock</td>
<td>normotensive (blood pressure stable in field and in OR)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>transiently hypotensive (blood pressure unstable in field but responsive to intravenous fluids)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>prolonged hypotension (systolic blood pressure &lt;90 mm Hg in field and responsive to intravenous fluid only in the OR)</td>
<td>2</td>
</tr>
<tr>
<td>ischemia (≤ 6 hours)</td>
<td>none (pulsatile limb without signs of ischemia)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>mild (diminished pulses without signs of ischemia)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>moderate (no pulse by Doppler, sluggish capillary refill, paresthesia, diminished motor activity)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>severe (pulseless, cool, paralyzed, numb, without capillary refill)</td>
<td>3</td>
</tr>
<tr>
<td>ischemia (&gt;6 hours)</td>
<td>none (as above)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>mild (as above)</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>moderate (as above)</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>severe (as above)</td>
<td>6</td>
</tr>
<tr>
<td>age</td>
<td>&lt; 30 years of age</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>≥ 30 and &lt;50 years of age</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>≥ 50 years of age</td>
<td>2</td>
</tr>
</tbody>
</table>

Scores for ischemia >6 hours are twice those of ≤ 6 hours.

Mangled Extremity Severity Score = (points for skeletal and soft tissue injury) + (points for blood pressure) + (points for ischemia, depending on duration of ischemia) + (points for age)

**Interpretation:**
Minimum score 1
Maximum score 14
A score ≥ 7 is 100% predictive for amputation in the study population.
A score <7 can usually be salvaged (105).

*Limb Salvage Index (LSI)*

Overview:
The Limb Salvage Index (LSI) is used to evaluate a severely injured lower extremity.

Parameters include:
1. artery
2. nerve
3. bone
4. skin
5. muscle
6. deep vein
7. warm ischemia time

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Finding</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>artery</td>
<td>artery contusion, intimal tear, partial laceration or avulsion (pseudo-aneurysm) with no distal thrombosis and palpable pedal pulses</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>complete occlusion of 1 of 3 shank vessels or profunda</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>occlusion of 2 or more shank vessels</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>complete laceration, avulsion, or thrombosis of femoral or popliteal vessels without palpable pedal pulses</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>complete occlusion of femoral or popliteal vessels with no distal runoff available</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>complete occlusion of 3 shank vessels with no distal runoff available</td>
<td>2</td>
</tr>
<tr>
<td>nerve</td>
<td>contusion or stretch injury</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>minimal clean laceration of femoral, peroneal or tibial nerve</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>partial transection or avulsion of sciatic nerve</td>
<td>1</td>
</tr>
<tr>
<td><strong>bone</strong></td>
<td>complete or partial transection of femoral, peroneal or tibial nerve</td>
<td>1</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>---------------------------------------------------------------------</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>complete transection or avulsion of sciatic nerve</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>complete transection or avulsion of both peroneal and tibial nerves</td>
<td>2</td>
</tr>
<tr>
<td>closed fracture at 1 or 2 sites</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>open fracture with comminution or with minimal displacement</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>closed dislocation without fracture</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>open joint without foreign body</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>fibula fracture</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>closed fracture at 3 or more sites on same extremity</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>open fracture with comminution or moderate to large displacement</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>segmental fracture</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>fracture dislocation</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>open joint with foreign body</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>bone loss &lt;3 cm</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>bone loss ≥ 3 cm</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>type III-B or III-C fracture (open fracture with periosteal stripping, gross contamination, extensive soft tissue injury or loss)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>skin</strong></td>
<td>clean laceration, single or multiple</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>small avulsion injury with primary closure</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>first degree burn</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>delayed closure due to contamination</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>large avulsion requiring split thickness skin graft or flap closure</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>second and third degree burn</td>
<td>1</td>
</tr>
<tr>
<td><strong>muscle</strong></td>
<td>laceration or avulsion involving a single compartment</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>laceration or avulsion involving a single tendon</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>laceration or avulsion involving 2 or more compartments</td>
<td>1</td>
</tr>
</tbody>
</table>
Shank is the lower leg.

Bone loss was <3 cm or >3 cm in the table. I assigned = 3 cm as 2 points.

Points for each category = maximum single point assignment

Limb Salvage Index = SUM (points for all 7 parameters)

**Interpretation:**
- Minimum score: 0
- Maximum score: 14
  - A higher score indicates a more severe injury.

<table>
<thead>
<tr>
<th><strong>Limb Salvage Index</strong></th>
<th><strong>Outcome</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>0−5</td>
<td>limb salvage successful (51 of 51)</td>
</tr>
<tr>
<td>6−14</td>
<td>amputation (19 of 19)</td>
</tr>
</tbody>
</table>

*Nerve Injury, Ischemia, Soft-Tissue Injury, Skeletal Injury, Shock, and Age (NISSSA) Score*
Overview:
The NISSSA score is used for grading the severity of an open fracture of the lower extremity. It is a modification of the MESS, with addition of an evaluation of nerve injury.

Parameters include:
1. N = nerve injury
2. I = ischemia
3. S = soft tissue contamination
4. S = skeletal injury
5. S = shock
6. A = age of the patient

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Finding</th>
<th>Description</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>nerve</td>
<td>sensate</td>
<td>no major nerve injury</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>dorsal</td>
<td>deep or superficial peroneal nerve, femoral nerve</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>plantar partial</td>
<td>tibial nerve injury</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>plantar complete</td>
<td>sciatic nerve injury</td>
<td>3</td>
</tr>
<tr>
<td>ischemia</td>
<td>none</td>
<td>good to fair pulses, no ischemia</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>mild ≤ 6 hours</td>
<td>reduced pulses but perfusion normal</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>moderate ≤ 6 hours</td>
<td>no pulse; prolonged capillary refill; Doppler pulses present</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>severe ≤ 6 hours</td>
<td>pulseless, cool, ischemic, no Doppler pulses</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>mild &gt;6 hours</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>moderate &gt;6 hours</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>severe &gt;6 hours</td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>soft tissue</td>
<td>low</td>
<td>minimal to no contusion, no contamination</td>
<td>0</td>
</tr>
<tr>
<td>Parameter</td>
<td>Injury Severity</td>
<td>Description</td>
<td>Score</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------</td>
<td>-------------</td>
<td>-------</td>
</tr>
<tr>
<td>Skeletal</td>
<td>Medium</td>
<td>Low energy: spiral fracture, oblique fracture, no or minimal displacement</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>Medium energy: transverse fracture, minimal comminution, small caliber gunshot wound</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>High energy: moderate displacement, moderate comminution, high velocity gunshot wound, butterfly fragments</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Severe</td>
<td>Severe energy: segmental, severe comminution, severe bone loss</td>
<td>3</td>
</tr>
<tr>
<td>Shock</td>
<td>Normotensive</td>
<td>Always &gt;90 mm Hg systolic</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Transient</td>
<td>Transient hypotension</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Persistent</td>
<td>Persistent hypotension despite fluids</td>
<td>2</td>
</tr>
<tr>
<td>Age</td>
<td>&lt;30 years</td>
<td>Young</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>30–50 years</td>
<td>Middle age</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>&gt;50 years</td>
<td>Older</td>
<td>2</td>
</tr>
</tbody>
</table>

NISSSA score = SUM (points for all 6 parameters)

**Interpretation:**
- Minimum score: 0
- Maximum score: 19
- A higher score indicates a more severe injury.
- A score ≥ 7 was 100% sensitive for amputation, but with specificity of 46%.
- A score ≥ 11 had a 100% specificity and positive predictive value for amputation.

(107)

*Hannover Fracture Scale-98 (HFS-98)*
Overview:
The Hannover Fracture Scale '98 is an update to the Hannover Fracture Scale that was developed in 1983. It is a simpler instrument yet reliable measure of limb salvage.

Parameters include:
1. extent of fracture bone loss
2. skin injury as percent of limb circumference
3. muscle injury as percent of limb circumference
4. wound contamination
5. deperiostation
6. local circulation
7. systolic blood pressure (systemic circulation)
8. neurologic findings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Finding</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>extent of bone loss</td>
<td>none</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0.1 to 1.9 cm</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>≥ 2.0 cm</td>
<td>2</td>
</tr>
<tr>
<td>skin injury</td>
<td>none</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1−24% of circumference</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>25−50% of circumference</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>51−75% of circumference</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>76−100% of circumference</td>
<td>4</td>
</tr>
<tr>
<td>muscle injury</td>
<td>none</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>1−24% of circumference</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>25−50% of circumference</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>51−75% of circumference</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>76−100% of circumference</td>
<td>4</td>
</tr>
<tr>
<td>wound contamination</td>
<td>none</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>partial</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>massive</td>
<td>2</td>
</tr>
<tr>
<td>Parameter</td>
<td>Options</td>
<td>Score</td>
</tr>
<tr>
<td>----------------------------</td>
<td>--------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>deperiostation</td>
<td>no</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>yes</td>
<td>1</td>
</tr>
<tr>
<td>local circulation</td>
<td>normal</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>capillary pulse</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>ischemia &lt;4 hours</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>ischemia 4 to 8 hours</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>ischemia &gt;8 hours</td>
<td>4</td>
</tr>
<tr>
<td>systolic blood pressure</td>
<td>constantly &gt;100 mm Hg</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>&lt;100 until admission</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>&lt;100 until surgery</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>constantly &lt;100 mm Hg</td>
<td>3</td>
</tr>
<tr>
<td>palmar-plantar sensibility</td>
<td>yes</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>no</td>
<td>1</td>
</tr>
<tr>
<td>finger-toe active motion</td>
<td>yes</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>no</td>
<td>1</td>
</tr>
</tbody>
</table>

Hannover Fracture Scale Score = SUM (points for all 8 parameters)

Interpretation:
- Minimum score: 0
- Maximum score: 22
- A higher score indicates a worse injury.
- A score ≥ 11 indicates significant trauma, with amputation recommended (108).

When assessing the damage caused to an extremity, emergency treatment personnel will use the scoring systems listed above. A determination regarding which system to use will be made based on the specific area that is damaged (109). Each scoring system is reliable. However, no system is 100% reliable. Therefore, practitioners should use the scoring system as an initial guide when making a determination regarding whether to amputate a damaged limb. However, practitioners should also exercise caution when relying completely on
the score. In some instances, the score will not accurately determine whether a limb should be amputated or salvaged (30).

*Treatment*

The loss of a limb requires both short term and long term care. Initial treatment involves minimizing the damage caused to the extremities and halting any additional limb loss (110). Once a limb has been lost, either directly during the accident or through amputation, it is necessary to treat the open wound and ensure that the area is cleaned and infection free. Therefore, emergency personnel will remove any additional damaged tissue, close up the open areas and provide wound care for the damaged tissue (101). In the first few weeks after the limb is lost, treatment will primarily involve managing the healing process and preventing any further damage and infection (103).

Once a patient has healed from the initial loss, treatment will shift to long-term management. Patients will often receive a prosthetic device to replace the lost limb. In some smaller areas, such as the fingers and toes, prosthetic devices are not available. Patients who are eligible for prosthetic devices will work with treatment providers to obtain and utilize the device. Initial care will involve learning to use, clean and maintain the prosthetic (102). Long-term treatment also includes physical therapy. Due to the change in gait or body function that results from the loss of an extremity, many patients require physical therapy to be able to move their bodies and regain basic mobility functions (111).

*Burns*

Burns often occur during instances of polytrauma as they are a common injury from explosions, fires, industrial accidents, car accidents, and many chemical induced accidents. Burns fall into four categories; with first degree burns being the mildest and fourth degree burns being the most severe (112). In most cases of polytrauma, patients typically develop second-degree burns or higher, with the
The majority of burn cases being third degree (113). In extreme instances, patients will present with fourth degree burns. First-degree burns are not common injuries in polytrauma cases (112).

Trauma related burns are most common in fires, blast related accidents, car accidents, industrial accidents and other chemical induced accidents. However, they can occur during any accident that involves some type of burning agent. The specific type of burn injury is dependent on the agent involved (114). Treatment for the burn will differ depending on the type of burn injury and the specific burn agent involved. The University of New Mexico provides the following table of the different types of burns:

**Types of Burn Injury**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thermal</strong></td>
<td><strong>Flash</strong> - Explosions of natural gas, propane, gasoline and other flammable liquids. Intense heat for a very brief period of time. Clothing is protective unless it ignites.</td>
</tr>
<tr>
<td></td>
<td><strong>Flame</strong> - Exposure to prolonged, intense heat. House fires, improper use of flammable liquids, automobile accidents, ignited clothing from stoves/heaters.</td>
</tr>
<tr>
<td></td>
<td><strong>Scalds</strong> - Burns caused by hot liquids. Water, oil, grease, tar, oil. Water at 140 degrees F, creates a deep burn in 3 seconds, but at 156 degrees F will cause the same injury in 1 second. (Coffee is 180 degrees F just brewed). Circumferential burns should raise suspicion of non-accidental trauma. Tar needs to be removed either with an adhesive remover solution or petroleum based dressings.</td>
</tr>
<tr>
<td></td>
<td><strong>Contact</strong> - Result from hot metals, plastics, glass or coals. Can be very deep.</td>
</tr>
<tr>
<td><strong>Chemical</strong></td>
<td>Caused by strong acids or alkali substances. They continue to cause damage until the agent is inactivated. Alkali substances usually cause more severe injury since they react with the lipids in the skin.</td>
</tr>
<tr>
<td><strong>Electrical</strong></td>
<td>Caused by either AC or DC current. Current follows the path of least resistance and causes injury in areas other than the contact/entry site. They cannot be judged from the external injury alone. High voltage &gt; 1,000 volts, low voltage &lt; 1,000 volts and lightening. Electrical burns are thermal burns from very high heat.</td>
</tr>
<tr>
<td><strong>Radiological</strong></td>
<td>Caused by alpha, beta or gamma radiation. They may need to have some type of decontamination done to stop the injury.</td>
</tr>
</tbody>
</table>
When a patient is being treated for burn trauma, the first step is to assess the burn and determine the degree of the burn (115). This is accomplished through a physical examination of the burn area. As part of the physical examination, the provider determines the physical attributes of the burn. This information is used to establish the degree level of the burn (116). Burns are categorized based on the severity of the burn, the depth of the burn, the characteristics of the burn and how widespread is the burn (117). Most polytrauma patients experience second, third and fourth degree burn trauma.

The University of New Mexico provides the following information regarding the four degrees of burns (113):

*Burn Classification*

*Note: The list below shows 4 burn degrees. While most of the public does not recognize the 4th degree, it is the correct term. The table below, with 3 degrees, is also correct. Both are acceptable.*

*Determining burn depth is important. Things to consider are temperature, mechanism, duration of contact, blood flow to skin, and anatomic location. Epidermal depth varies with body surface, which can offer varying degrees of thermal protection. Older adults and young children also have thinner skin.*

*First degree:*

- Includes only the outer layer of skin, the epidermis
- Skin is usually red and very painful
- Equivalent to superficial sunburn without blisters
- Dry in appearance
- Healing occurs in 3-5 days, injured epithelium peels away from the healthy skin
- Hospitalization is for pain control and maybe fluid imbalance
Second degree: Can be classified as partial or full thickness.

- **Partial thickness**
  - Blisters can be present
  - Involve the entire epidermis and upper layers of the dermis
  - Wound will be pink, red in color, painful and wet appearing
  - Wound will blanch when pressure is applied
  - Should heal in several weeks (10-21 days) without grafting, scarring is usually minimal

- **Full thickness**
  - Can be red or white in appearance, but will appear dry.
  - Involves the destruction of the entire epidermis and most of the dermis
  - Sensation can be present, but diminished
  - Blanching is sluggish or absent
  - Full thickness will most likely need excision & skin grafting to heal

Third degree:

- All layers of the skin is destroyed
- Extend into the subcutaneous tissues
- Areas can appear, black or white and will be dry
- Can appear leathery in texture
- Will not blanch when pressure is applied
- No pain

Fourth degree:

- Full thickness that extends into muscle and bone

Once the burn has been classified, providers will work to administer the appropriate treatment. Treatment differs depending on the type of burn, the classification, and the burn agent used.
Burn Treatment
Depending on the severity of the burns, patients will require different types of treatment. During the initial emergency assessment and treatment process, the patient’s burns will be evaluated to determine the degree of burn, the cause of the burn, and the necessary treatment needed. If a burn is the result of some sort of chemical, it will require immediate treatment, as some chemicals will continue to burn the skin until they are properly removed or diluted (118). With other types of burn injuries, immediate treatment is also necessary to counter the affects of the burn agent and to minimize further damage to the affected area. Immediate care will also reduce the chances of the patient developing burn related complications (119).

In addition to immediate emergency care, the patient may also require long-term treatment to assist with the healing process and reduce the chances of the patient developing further complications (114). Mild burns will require minimal treatment and are not included in the following treatment recommendations. The following treatment recommendations are intended for burns that are moderate, severe and/or widespread.

Medications
In many burn traumas, the patient will require medications to assist with recovery and prevent further complications. Various medications may be used depending on the cause and the severity of the burns, as well as any other relevant complications.

- Intravenous (IV) Fluids –
  Many burn patients will require intravenous (IV) fluids to prevent dehydration and to minimize the risk of organ failure (120).
- Pain Relievers –
  Pain relievers are often administered immediately to relieve some of the pain and discomfort caused by the injury. While patients may not experience pain immediately after the injury occurs due to shock and
initial nerve damage, the pain medication will prevent the patient from experiencing discomfort as the burn begins to heal. Morphine is the most common pain reliever used. However, other pain relievers can be administered depending on the needs of the patient (116).

- **Anti Anxiety Medication** –
  Many patients experience extreme distress when a burn trauma occurs. In cases of severe, widespread burns, the distress is even more severe (121). The distress and anxiety caused by the injuries can cause the patient to act erratically and may result in further damage. Many patients require anti anxiety medication or sedatives of some sort; and, providing anti anxiety medication enables the initiation of treatment without causing further distress to the patient (114).

- **Burn creams** –
  Burn creams are used to promote healing of the affected area and minimize discomfort. Burn creams work by keeping the injured area moist. They also reduce pain, prevent infection and increase the rate of healing (122).

- **Antibiotics** –
  Antibiotics are used to prevent further infection. Since a burn patient is at risk of developing sepsis from bacteria entering the bloodstream, antibiotics are used to minimize the amount of bacteria that enters the body (123).

- **Tetanus shot** –
  Depending on the type of burn and the agent that caused it, a patient may require a tetanus shot. These are often used when burns are caused by explosions that may have involved flying debris, or contact with foreign objects (120).

*Physical therapy*

Due to the damage caused by burns, a patient may require physical therapy. In cases where the burn is widespread and covers joints, the patient will experience
difficulty moving and may suffer severe damage to the joints and ligaments. Physical therapy will help stretch the patient’s skin so that the joints can regain flexibility. Physical therapy is also used to help patients develop muscle strength and coordination if the burn has caused damage in those areas (114).

**Surgical and other procedures**
Patients with severe trauma will often require surgical procedures or other procedures that will minimize the damage and assist with patient stabilization.

**Breathing assistance**
When burns occur on the face or neck, the patient may experience difficulty with breathing due to the impact on the airway. In some instances, the patient’s throat may swell to the point of closure. When this occurs, or even when there is a risk of this occurring, the patient will require breathing assistance. Therefore, a tracheal tube will be inserted in the trachea to provide assistance and continue to supply oxygen to the lungs (124).

**Tube feeding**
In cases that involve burns to the throat or mouth, a patient may be unable to ingest food. Therefore, a feeding tube will be inserted so that the patient can receive proper nutrition, which will help expedite the healing process (114).

**Decompression**
When a burn begins to heal, a scab, or eschar, will develop. In some instances, this scab may wrap entirely around the patient’s limb, thereby tightening and cutting off blood circulation. Eschars that form around areas such as the chest pose the risk of causing difficulty breathing. To reduce the impact of eschars that wrap around these areas, treatment may involve cutting the eschar in several places. This minimizes the pressure to these areas and reduces the risk of further complications (123).
**Skin grafts**
In severe burn cases the skin is so severely damaged that it may not be able to heal properly. This is especially common with deep burns, as the scar tissue caused by these burns will prevent the area from healing properly. In these instances, the patient will require a skin graft to help replace the scar tissue that is caused by the deep burns. Some patients are able to use sections of their own healthy skin. However, in some cases, donor skin from cadavers or pigs may be needed temporarily while the patient’s skin heals enough to use. Donor skin may also be used when the burns cover the entire body and there is no healthy skin to use (125).

**Reconstruction**
Severe burns cause permanent damage to the skin. In many instances, the skin damage is purely cosmetic. In other instances, the skin damage causes other problems, such as reducing joint flexibility. In both instances, plastic surgery may be required to improve the appearance of the burn areas and/or improve the patient’s joint flexibility (119).

In some cases, patients will require further treatment at a burn trauma center. This determination is made after the patient is stabilized and all other trauma related injuries have been addressed and treated (123). While burns require immediate treatment, many other trauma-related injuries will present a more immediate danger to the patient and may be life threatening. Therefore, emergency personnel will assess the patient’s burn injuries during the initial assessment and emergency treatment stage, but the referral to a burn trauma center will only occur after the patient has been treated and determined stable (126).

Initial burn treatment will focus on preventing further burns and minimizing the initial damage. Once the patient is stable, the provider will determine if further burn treatment and care will be conducted at the hospital, in the patient’s home,
or at a burn trauma center (124). Burn trauma centers are used to treat severe burns in both children and adults, and the length of treatment will vary depending on the type of burn, the severity of the burn, the needs of the patient, and the speed of recovery (114). Burn injuries that should be referred to a burn unit include the following:

1. Partial thickness burns greater than 10% total body surface area (TBSA)
2. Burns that involve the face, hands, feet, genitalia, perineum, or major joints
3. Third-degree burns in any age group
4. Electrical burns, including lightning injury
5. Chemical burns
6. Inhalation injury
7. Burn injury in patients with preexisting medical disorders that could complicate management, prolong recovery, or affect mortality
8. Any patients with burns and concomitant trauma (such as fractures) in which the burn injury poses the greatest risk of morbidity or mortality. In such cases, if the trauma poses the greater immediate risk, the patient may be initially stabilized in a trauma center before being transferred to a burn unit. Physician judgment will be necessary in such situations and should be in concert with the regional medical control plan and triage protocols.
9. Burned children in hospitals without qualified personnel or equipment for the care of children
10. Burn injury in patients who will require special social, emotional, or long-term rehabilitative intervention (123)

Burn centers are located throughout the United States. A patient is typically transported to the nearest burn center. However, in some instances, a patient will be transported to the burn center that is best able to treat the specific type of burn that the patient has incurred (126). Most burn centers are equipped to treat all types of burns. However, some burn centers specialize in specific burn type
and treatment. In addition, some burn centers do not provide pediatric burn treatment. Therefore, a pediatric patient may have to be admitted to a burn center that is not geographically nearby (123). The following table provides information on the burn trauma centers located within the United States:

<table>
<thead>
<tr>
<th>Burn Center Name</th>
<th>City</th>
<th>Verification Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona Burn Center at Maricopa Medical Center</td>
<td>Phoenix</td>
<td>11/19/12 to 11/19/15</td>
</tr>
<tr>
<td>Arkansas Children's Hospital</td>
<td>Little Rock</td>
<td>5/25/10 to 5/25/13</td>
</tr>
<tr>
<td>LAC+USC Medical Center Burn Center</td>
<td>Los Angeles</td>
<td>2/1/12 to 2/1/15</td>
</tr>
<tr>
<td>UCI Regional Burn Center</td>
<td>Orange</td>
<td>1/11/10 to 1/11/13</td>
</tr>
<tr>
<td>Shriner's Hospital for Children - Northern California Pediatric Burn Center</td>
<td>Sacramento</td>
<td>2/17/12 to 2/17/15</td>
</tr>
<tr>
<td>UC Davis Regional Burn Center Adult Burn Center</td>
<td>Sacramento</td>
<td>2/17/12 to 2/17/15</td>
</tr>
<tr>
<td>University of California San Diego</td>
<td>San Diego</td>
<td>6/2/12 to 6/2/15</td>
</tr>
<tr>
<td>Saint Francis Memorial Hospital Bothin Burn Center</td>
<td>San Francisco</td>
<td>9/16/11 to 9/16/14</td>
</tr>
<tr>
<td>Santa Clara Valley</td>
<td>San Jose</td>
<td>5/23/11 to 5/23/14</td>
</tr>
<tr>
<td>Torrance Memorial Medical Center Burn Center</td>
<td>Torrance</td>
<td>6/3/13 to 6/3/16</td>
</tr>
<tr>
<td>University of Colorado Hospital Burn Center</td>
<td>Denver</td>
<td>11/6/11 to 11/6/14</td>
</tr>
<tr>
<td>Bridgeport Hospital Panettieri Burn Center</td>
<td>Bridgeport</td>
<td>6/10/11 to 6/10/14</td>
</tr>
<tr>
<td>Washington Hospital Center Adult Burn Center</td>
<td>Washington</td>
<td>3/18/10 to 3/18/13</td>
</tr>
<tr>
<td>University of Florida Shands Burn Center Adult Burn Center</td>
<td>Gainesville</td>
<td>2/25/10 to 2/25/13</td>
</tr>
<tr>
<td>University of Miami Jackson Memorial Hospital Burn Center</td>
<td>Miami</td>
<td>6/16/11 to 6/16/14</td>
</tr>
<tr>
<td>Tampa Bay Regional Burn</td>
<td>Tampa</td>
<td>8/26/10 to 8/26/13</td>
</tr>
<tr>
<td>Center</td>
<td>City</td>
<td>Dates</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>-----------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td><strong>GEORGIA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grady Memorial Hospital Burn Center</td>
<td>Atlanta</td>
<td>4/10/12 to 4/10/15</td>
</tr>
<tr>
<td>Joseph M. Still Burn Center</td>
<td>Augusta</td>
<td>2/11/10 to 2/11/13</td>
</tr>
<tr>
<td><strong>ILLINOIS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Chicago Burn Center</td>
<td>Chicago</td>
<td>4/3/12 to 4/3/15</td>
</tr>
<tr>
<td>Loyola University Medical Center</td>
<td>Maywood</td>
<td>2/28/11 to 2/28/14</td>
</tr>
<tr>
<td><strong>INDIANA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. Joseph Hospital</td>
<td>Fort Wayne</td>
<td>6/16/11 to 6/16/14</td>
</tr>
<tr>
<td>Indiana University Riley Burn Unit</td>
<td>Indianapolis</td>
<td>9/5/11 to 9/5/14</td>
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Patients who are not referred to burn trauma centers will often require long-term treatment at the hospital. Depending on the scope and severity of the burn, the patient may need to stay for a significant length of time. However, once a patient requires an advanced level of treatment, he or she is often referred to the burn trauma center. In polytrauma cases, when a patient is receiving treatment for multiple injuries, the burn trauma center may not be a feasible option. In those instances, the patient will receive advanced, long-term care at the hospital as part of a comprehensive treatment program (114).
The National Hospital Discharge Survey tracks the number of hospitalizations at both standard hospitals and hospital burn centers. According to the 2010 data provided by the National Hospital Discharge Survey, the number of hospitalizations related to burn injury totaled 40,000, with 30,000 of those occurring at hospital burn centers. Over 60% of the estimated U.S. acute hospitalizations related to burn injury were admitted to 127 burn centers. Such centers now average over 200 annual admissions for burn injury and skin disorders requiring similar treatment. The other 4,500 U.S. acute care hospitals average less than 3 burn admissions per year (126).

In addition to the data above, the American Burn Association National Burn Repository provides more detailed statistics regarding the survival rate, gender, ethnicity, admission cause and place of occurrence for each burn admission to a hospital burn center. According to the American Burn Association, the statistical data for burn center admission from 2002 – 2011 is as follows:

- Survival Rate: 96.1%
- Gender: 69% male, 31% female
- Ethnicity: 59% Caucasian, 19% African-American, 15% Hispanic, 7% Other
- Admission Cause: 44% fire/flame, 33% scald, 9% contact, 4% electrical, 3% chemical, 7% other
- Place of Occurrence: 69% home, 9% occupational, 7% street/highway, 5% Recreational/Sport, 10% Other (128)

**Burn Related Complications**

In addition to the injuries that are caused by the burn, patients may also experience additional complications. While these complications are not burn symptoms, and can occur as complications of other injuries, they are directly caused by burn trauma. In fact, burns often cause additional complications in a patient that extend beyond the basic injury. Complications are more common with deep burns or burns that are widespread (112). Depending on the severity
and cause of the burn, patients may experience one or more of the following complications listed below.

**Infection:**
The more severe a burn, the more an individual is prone to infection. Second degree and higher burns cause breaks in the skin that increase the individual's vulnerability to infection. In the mildest cases of infection, bacteria can infect the burn area directly, which is problematic. However, in more severe cases, the bacteria can infect the whole body.

Once the bacteria enter the body through the open wound, they can travel through the bloodstream and infect the entire body, thereby causing sepsis. Sepsis progresses rapidly and often causes shock to the individual, which results in organ failure and, ultimately, death (117).

**Hypovolemia:**
Hypovolemia, or low blood volume, occurs as a result of damage to the blood vessels. Deep burns can cause damage to the blood vessels, which results in a loss of fluid and can cause low blood volume. Once a patient experiences blood and fluid loss, the heart is unable to pump enough blood to the body, thereby causing further damage and possibly resulting in death (113).

**Hypothermia:**
Hypothermia, which is dangerously low body temperature, is a common complication when a patient sustains widespread burns. Widespread burns damage a large portion of the skin. Since the skin helps control the body’s temperature, the damage caused by widespread burns impacts the skin’s ability to control temperature. Therefore, when a large portion of the skin is damaged, the individual will experience significant heat loss, which increases the chances of the patient developing hypothermia (124).
Breathing (respiratory) problems:
Skin damage is the primary injury caused by burns. However, hot air and smoke can also cause burns to an individual’s lungs (120).

Bone and joint problems:
Deep burns cause significant damage to the individual. Due to the severity of the damage, an individual may experience limited movement in his or her bones and joints. This is a result of the formation of scar tissue, which forms and causes contractures. Contractures are caused when skin, muscles and tendons shorten and tighten. Once this occurs, the joints are permanently pulled out of position, which impacts the individual’s ability move properly (124).

Fractures
Fractures are common polytrauma injuries as many of the causes of polytrauma involve significant impact. While fractures are not life threatening, their inclusion with other trauma injuries is necessary as they can impact the treatment and healing of the trauma patient. In the simplest terms, a fracture is an area of the bone that is broken. However, there are different types and severity levels of fractures. Depending on the cause and the impact, a polytrauma patient may experience any level and type of fracture (73).

There are two categories of fractures: closed fractures and compound fractures. A closed fracture is one in which there is a clean break to the bone. With this type of fracture, there is no damage to the surrounding tissue and the bone does not tear through the skin (129). A compound fracture is more complex. With this type of fracture, the surrounding tissue and skin can be damaged, resulting in significant bruising. A compound fracture may also involve the bone tearing through the skin (130). Within these two categories of fractures, there are many different types. The areas they affect, the damage they inflict, and the cause of the fracture define these fracture types.
Types of Fractures (129) are listed below:

- Avulsion fracture - a muscle or ligament pulls on the bone, fracturing it.
- Comminuted fracture - the bone is shattered into many pieces.
- Compression (crush) fracture - generally occurs in the spongy bone in the spine. For example, the front portion of a vertebra in the spine may collapse due to osteoporosis.
- Fracture dislocation - a joint becomes dislocated, and one of the bones of the joint has a fracture.
- Greenstick fracture - the bone partly fractures on one side, but does not break completely because the rest of the bone can bend. More common among children, whose bones are softer and more elastic.
- Hairline fracture - a partial fracture of the bone. Often this type of fracture is harder to detect.
- Impacted fracture - when the bone is fractured, one fragment of bone goes into another.
- Longitudinal fracture - the break is along the length of the bone.
- Oblique fracture - A fracture that is diagonal to a bone’s long axis.
- Pathological fracture - when an underlying disease or condition has already weakened the bone, resulting in a fracture (bone fracture caused by an underlying disease/condition that weakened the bone).
- Spiral fracture - A fracture where at least one part of the bone has been twisted.
- Stress fracture - more common among athletes. A bone breaks because of repeated stresses and strains.
- Torus (buckle) fracture - bone deforms but does not crack. More common in children. It is painful but stable.
- Transverse fracture - a straight break right across a bone.

When assessing a trauma patient, it is important to identify any present fractures, as untreated fractures can cause further damage (73). In patients that are unconscious, this can be difficult as there is no verbal indication of the common
Fracture symptoms (131). Therefore, in these instances, X-rays will be used to identify fractures and other injuries in those areas affected by the trauma (132). Examination of different areas will also show signs of potential fractures, as there may be swelling or bruising. In extreme cases, the bone will be protruding from the area. When a patient is conscious, it can be easier to identify fracture sites as the patient can communicate information regarding any pain (73).

Fracture symptoms (129) are listed below:

- Pain and swelling at the fracture site.
- Tenderness close to the fracture.
- Paleness and deformity (sometimes).
- Loss of pulse below the fracture, usually in an extremity (this is an emergency).
- Numbness, tingling or paralysis below the fracture (rare; this is an emergency).
- Bleeding or bruising at the site.
- Weakness and inability to bear weight.

**Treatment**

Treatment for broken bones involves putting the pieces back into position and preventing them from moving out of place as they heal. The healing process involves the broken bone ends “knitting” themselves back together and forming new bone around the edges of the broken areas (133). In some fracture cases, surgery may be required (134).

Depending on the severity of the break and the location of the injury, different treatments will be used. The following is a description of the different treatments that are used to treat fractures (130):

- Cast Immobilization
A plaster or fiberglass cast is the most common type of fracture treatment, because most broken bones can heal successfully once they have been repositioned and a cast has been applied to keep the broken ends in proper position while they heal.

- **Functional Cast or Brace**
  The cast or brace allows limited or "controlled" movement of nearby joints. This treatment is desirable for some, but not all, fractures.

- **Traction**
  Traction is usually used to align a bone or bones by a gentle, steady pulling action.

- **External Fixation**
  In this type of operation, metal pins or screws are placed into the broken bone above and below the fracture site. The pins or screws are connected to a metal bar outside the skin. This device is a stabilizing frame that holds the bones in the proper position while they heal. In cases where the skin and other soft tissues around the fracture are badly damaged, an external fixator may be applied until surgery can be tolerated.

- **Open Reduction and Internal Fixation**
  During this operation, the bone fragments are first repositioned (reduced) in their normal alignment, and then held together with special screws or by attaching metal plates to the outer surface of the bone. The fragments may also be held together; and, this is done by inserting rods down through the marrow space, in the center of the bone.

*Complications of Fracture Repair and Fractures*

It is important to properly treat and repair fractures as soon as possible to prevent the patient from experiencing any further damage as well as any repair.
related complications. In some instances, repair related complications might be unavoidable (135); however, repairing the fracture early and properly can prevent others. It is important to understand the pathophysiology and predisposing factors of fracture repair complications to adequately prevent them. When a complication is unavoidable, it is important to diagnose it early and provide the appropriate treatment so that it does not cause further damage (133).

While some complications can be a direct result of fracture repair, other complications occur as a result of the fracture itself. Complications are categorized as either acute or delayed, and they range in severity from minimal to life threatening (136). Acute complications occur as a direct result of the trauma sustained and can include damage to vascular structures, nerves, or soft tissue (73). Delayed complications may occur after initial treatment or in response to treatment (135). As part of the trauma treatment process, it is important to identify and treat any fracture related complications to prevent further damage (133). In addition, reevaluation at regular intervals during healing is necessary to monitor progress and identify any complications that may arise (134).

The following complications are common in fracture repair or as the direct result of a fracture.

- Life-Threatening Conditions:
  In some instances, a patient will experience a life threatening complication as the result of a fracture. These conditions include the following:
  - Femur fractures - disrupt the femoral artery or its branches and are potentially fatal.
  - Pelvic fractures - damage pelvic arteries or veins causing life-threatening hemorrhage
  - Hip fractures - may prevent ambulation, resulting in potentially life-threatening complications, such as pneumonia, thromboembolic
disease, and possibly rhabdomyolysis, if there is a prolonged period of immobility
o Multiple-rib fractures - substantial risk for pulmonary contusion and related complications. (137)

- Arterial Injury:
  Some patients may experience immediate or delayed arterial injuries as the result of fractures or dislocations. These complications include:
  - Immediate:
    o Laceration of the vessel, either partial or complete
    o Occlusion, either partial or complete, which may be due to:
      - angulation
      - extrinsic compression
      - intimal tears and dissection with an intact adventitia
      - stretching
      - spasm
  - Delayed:
    o False aneurysms
    o AV fistula
    o Thrombosis of the vessel following reconstructive surgery
    o Ischemic muscle contractures (138).

- Nerve Injury:
  Nerve injuries and vessel injuries are common complications with some types of fractures. Due to the location of many nerves and vessels, they are prone to injury. The most vulnerable nerves and vessels are those that lie in close proximity to the bone. These injuries are common in both closed and open fractures. However, the injury is often more severe with an open fracture. Of the two, nerve injuries are more commonly complications of fractures (136).
• Compartment Syndrome:
Compartment syndrome is the direct result of swelling and bleeding within a compartment. When this occurs, the fascis does not stretch, thereby causing increased pressure on the capillaries, nerves and muscles. This increased pressure disrupts blood flow to the muscles and nerve cells. When this occurs, the supply of oxygen is reduced, which damages nerve and muscle cells. There are two types of compartment syndrome:
  o Acute – This type results in permanent disability and tissue death unless the pressure is relieved quickly.
  o Chronic (exertional) – This type does not typically result in permanent disability and tissue death.

Compartment syndrome is most common in the anterior compartment of the lower leg, as well as other compartments in the leg. However, it can also occur in the arms, hands, feet and buttocks (139).

• Venous Thromboembolism:
Venous thromboembolism (VTE) is a term that describes a condition that occurs when clots or thrombi develop in the vein from red blood cells, fibrin and other components, which clump and form a mass. VTE is the result of at least one of three underlying etiologic factors: damage to endothelial lining of the blood vessel, stasis or slowing of the blood flow, and hypercoagulability or increased clotting of the blood.

Venous thromboembolism consists of two related conditions: deep vein thrombosis (DVT) that commonly occurs in leg veins, and pulmonary embolism (PE) that occurs when a segment of a clot, within the deep venous system detaches from the vessel, travels to the lungs, and lodges within the pulmonary arteries. (140)
• Osteomyelitis

Osteomyelitis is an infection that occurs in the bone. Typically, various microbial agents, such as staphylococcus aureus, cause osteomyelitis. In addition, osteomyelitis can occur during the following situations:

  o An open injury to the bone, such as an open fracture with the bone ends piercing the skin.
  o An infection from elsewhere in the body, such as pneumonia or a urinary tract infection that has spread to the bone through the blood (bacteremia, sepsis).
  o A minor trauma, which can lead to a blood clot around the bone and then a secondary infection from seeding of bacteria.
  o Bacteria in the bloodstream bacteremia (poor dentition), which is deposited in a focal (localized) area of the bone. This bacterial site in the bone then grows, resulting in destruction of the bone. However, new bone often forms around the site.
  o A chronic open wound or soft tissue infection can eventually extend down to the bone surface, leading to a secondary bone infection.

(141)

• Malunion:

In a malunion, the bone heals in a position that is considered unacceptable and which may cause significant impairment. In some instances, the bone heals in a bent angle. This is called an angulated heal (130). In other instances, the bone can be rotated out of position or can have overlapping fractured ends, which may cause bone shortening (130). Malunion is typically caused by the following factors:

  o inadequate immobilization of the fracture
  o misalignment at the time of immobilization
  o premature removal of the cast or other immobilizer (137).
• Nonunion:
A nonunion occurs when a fracture fails to heal after a number of months. A nonunion is often caused by the following factors:
  o The broken ends of bone may be separated too much (overdistruction)
  o There could have been excessive motion at the fracture site, either from inadequate immobilization after the injury or from having a cast removed prematurely
  o Muscle or other tissue caught between the fracture fragments also can prevent healing, as can the presence of infection or inadequate blood supply to the fracture site
  o Bone disease (e.g., bone cancer) also can prevent healing (73).

The two types of nonunions include:
  o Fibrous nonunion – fractures that heal through the formation of fiber tissue rather than the formation of new bone
  o False joint (pseudarthrosis) – continuous movement of the fracture fragments result in the development of a false joint (135).

The following types of fractures pose the greatest risk of nonunion:
  o Fractures of the wrist (carpus), including scaphoid bone
  o Certain fractures of the foot, including navicular fractures and Jones (diaphyseal) fractures of the fifth metatarsal
  o Shoulder long bone fractures (proximal humerus fractures)
  o Shin bone (tibial) fractures (130).

• Complex Regional Pain Syndrome (CRPS):
Complex regional pain syndrome is common in injuries that damage the peripheral and central nervous systems. CRPS is characterized by chronic pain that affects one of the limbs (arms, legs, hands or feet), which
occurs after there has been a trauma to the area (73). Symptoms of CRPS include:
  o prolonged or excessive pain
  o mild or dramatic changes in skin color, temperature, and/or swelling in the affected area (142).

There are two types of CRPS:
  o CRPS-I – patients do not have confirmed nerve injuries
  o CRPS-II – patients do have confirmed nerve injuries (142).

Both types of CRPS produce the same symptoms. Patients will experience a range of symptom severity and duration depending in the type of injury (73). Most CRPS cases are mild and resolve completely over time. However, in some instances, patients will present with a severe case, which may result in delayed recovery and long-term disability (142).

- Fat Embolism Syndrome:
  Some patients may develop fat embolism syndrome as the result of fractures to the long bones and pelvis. These fractures may result in the development of fat globules in the peripheral circulation and lung parenchyma of the patient. Fat embolism syndrome is a common occurrence, and affects almost all patients who experience a long bone or pelvic fracture. It is most common in closed fractures. In fact, patients with a single long bone fracture have a 1 to 3 percent chance of developing the syndrome, and this increases in correlation with the number of fractures (143).

- Post-Traumatic Arthritis:
  "Arthritis" is defined as inflammation of a joint. The most common cause is wearing out of joint surface cartilage (osteoarthritis). The wearing out of a joint that has had any kind of physical injury causes post-traumatic
arthritis. The injury could be from sports, a vehicle accident, a fall, a military injury, or any other source of physical trauma. Such injuries can damage the cartilage and/or the bone, changing the mechanics of the joint and making it wear out more quickly. The wearing-out process is accelerated by continued injury and excess body weight (144).

Fractures are common polytrauma injuries and must be treated accordingly. Although fractures are rarely life threatening, it is important to assess and treat them during the initial emergency treatment stage to prevent further damage. Fractures can range in severity from minor cracks to complete breaks that cause trauma to the surrounding tissue and skin. Therefore, practitioners must identify the extent of injury and provide the appropriate care to minimize further damage.

**Sensory Loss**

Sensory loss, which includes vision and hearing, is common in polytrauma. In some instances, the sensory loss will be temporary, as it is a result of initial damage. Once the patient has healed, sensory function returns (1). In other instances, sensory loss will be permanent. Permanent loss often occurs as the result of blast trauma, or other accidents, that cause significant, permanent damage to the eyes and ears (12). During the initial assessment and treatment stage, emergency personnel will attempt to identify the extent of damage and determine the potential outcome of the patient in regards to sensory functions (8). Treatment will be developed based on initial findings and the extent of damage (39).

*Loss of Vision and Ocular Injury*

Vision loss in polytrauma patients is typically a result of direct ocular injury or as a complication of traumatic brain injury (145). Vision loss occurs frequently in blast related trauma, car accidents, and industrial and chemical related accidents (146). In many instances, vision loss is caused by direct ocular damage.
Chemicals, debris, and other foreign objects can penetrate the eye and cause temporary or permanent damage (147). In other instances, head trauma will cause nerve damage that results in loss of vision (56). This loss can be temporary or permanent (145).

The outcomes for individuals with ocular injury will vary from complete blindness to full recovery. According to Castellarin et al:

“In the USA alone, there are approximately 2,000,000 eye injuries each year, and more than 40,000 result in permanent visual impairment. Eye injury is a leading cause of monocular blindness in the USA, and is second only to cataract as the most common cause of visual impairment. In a study to determine the type and frequency of ocular injuries in patients with major trauma, 16% of the major trauma cohort had ocular or orbital trauma. Of patients with injuries involving the face, 55% had ocular or orbital injuries.” (148)

The following is a list of the common causes and types of ocular injuries that may cause vision loss, either temporary or permanent (149):

- Blunt trauma
- Blowout Fracture
- Lid Lacerations
- Hyphaema
- Intraocular Foreign Body (IOFB)
- Penetrating Eye Injury (PEI)
- Chemical Burns
- Corneal Foreign Body/Abrasion
- Retinal/ Vitreous Injury
- Retrobulbar Hemorrhage
- Traumatic Optic Neuropathy
In trauma situations, vision loss is rarely assessed during initial treatment, unless the trauma is minimal and the vision loss is isolated (145). Typically, initial emergency treatment will focus on assessment and treatment of vital functions and any injuries that are severe or life threatening. If significant ocular damage is present, initial assessment and treatment will involve treating the damage and minimizing any further damage (150). However, if the ocular damage is not apparent or significant, vision loss will not be addressed immediately. Once the patient is stabilized, and all other types of trauma are treated, including trauma to the head, face, spine, and other essential organs, the emergency treatment team will begin to assess vision function (149). This is typically conducted in the emergency room so that treatment can begin immediately, if deemed necessary (8).

An initial ophthalmologic evaluation will be conducted and should be performed systematically to identify any complications. Many trauma patients are under such severe distress, and are often unconscious, which can cause them to be unaware of initial visual changes (145). In these instances, the patient may not identify any concerns about vision loss (149). Therefore, the evaluation should include direct questioning of the patient to gather information (145). The initial evaluation should also include an external inspection of the eyes, as well as the periorbital region. In addition, the assessment should include a measurement of visual acuity, pupillary examination, testing of extraocular movements and funduscopic examination (150).

During the ophthalmologic evaluations, the following assessment should be conducted on the specific areas:

<table>
<thead>
<tr>
<th>Area</th>
<th>Examination and Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conjunctiva</td>
<td>Fornix should be carefully examined, looking for foreign bodies sequestered in redundant folds. Hemorrhagic chemosis could be secondary to orbital fractures and/or open globe injuries. Laceration of the conjunctiva may be gently manipulated in order to rule out an underlying scleral wound or a subconjunctival foreign body.</td>
</tr>
</tbody>
</table>
Cornea

The corneal examination begins on the surface and proceeds more deeply. For epithelial defects, utilize topical fluorescein when necessary. If wounds are present, these must be carefully evaluated to determine if they are full thickness. A full-thickness wound leaks aqueous; this can be highlighted using 2% fluorescein (Seidel positive). If a foreign body extends into the anterior chamber (AC) (open globe), it should be removed in the operating room.

Sclera

The conjunctiva may remain intact overlying a full-thickness scleral wound; similarly, a full-thickness scleral wound may be distant from the conjunctival wound. Hemorrhage in or under the conjunctiva may also hide the scleral defect and/or prolapsed uveal tissue. Exploratory surgery is indicated when a scleral wound cannot be ruled out.

Anterior Chamber

The AC should be examined with the slit-lamp, looking for cells, flare, fibrin, hypopyon, and possible IOFBs. The depth of the chamber can also provide additional information; deepening can be seen with posterior dislocation or subluxation of the crystalline lens, iridodialysis, and scleral rupture. Shallowing can occur with anterior dislocation or subluxation of the crystalline lens, vitreous prolapse, leaking corneoscleral wound, suprachoroidal hemorrhage, serous choroidal detachment, aqueous misdirection, and angle closure.

Iris and Angle

Using direct illumination and retroilluminatun techniques, the iris should be examined for sphincter tears, iridodialysis, full-thickness laceration (stromal defect), and iridodonesis (indicative of lens subluxation). Gonioscopy can be useful in identifying an IOFB in the angle or, with gentle pressure, an occult wound.

Lens

The lens should be examined for phacodonesis, dislocation, defects in the anterior capsule with or without leakage of cortical material, posterior capsular defects or feathering, sectoral cataract, intralenticular foreign body, and zonular rupture (signaled by vitreous prolapse into the AC). Intraocular pressure should be deferred in eyes with obvious open globe injuries.

Ocular damage is classified during the initial examination using the Ocular Damage Classification Scale. This system is used to classify both open-globe and closed-globe injuries. It uses four separate variables (151):

- type of injury, based on the mechanism of injury
- grade of injury, defined by visual acuity in the injured eye at initial examination
- pupil, defined as the presence or absence of a relative afferent pupillary defect in the injured eye
- zone of injury, based on the anteroposterior extent of the injury
The following is the Ocular Damage Classification Scale:

Class of injury -
1. Open-globe: injury with full thickness wound to the corneosclera
2. Closed-globe: injury without full thickness defect of the corneosclera

Components to classification -
1. Type
2. Grade based on visual acuity, using (a) a Snellen chart at 20 ft or 6 meters, or (b) a Rosenbaum near card with correction and pinhole, when appropriate
3. Defect in pupillary response to light stimulus
4. Zone affected

<table>
<thead>
<tr>
<th>Type</th>
<th>Open-Globe</th>
<th>Closed-Globe</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Rupture</td>
<td>Contusion</td>
</tr>
<tr>
<td>B</td>
<td>Penetrating</td>
<td>lamellar laceration</td>
</tr>
<tr>
<td>C</td>
<td>intraocular foreign body</td>
<td>superficial foreign body</td>
</tr>
<tr>
<td>D</td>
<td>Perforating</td>
<td>Mixed</td>
</tr>
<tr>
<td>E</td>
<td>Mixed</td>
<td>N/A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Visual Acuity</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 20/40</td>
<td>1</td>
</tr>
<tr>
<td>20/50 to 20/100</td>
<td>2</td>
</tr>
<tr>
<td>19/100 to 5/200</td>
<td>3</td>
</tr>
<tr>
<td>4/200 to light perception</td>
<td>4</td>
</tr>
<tr>
<td>no light perception</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relative Afferent Pupillary Defect</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>present in the affected eye</td>
<td>positive</td>
</tr>
<tr>
<td>absent in the affected eye</td>
<td>negative</td>
</tr>
</tbody>
</table>

Assessing the pupillary response involves the following:
1. The testing is done with the swinging flashlight test.
2. If the injured eye is mechanically or pharmacologically nonreactive, or if there is media opacity, then a consensual response in the fellow eye is considered negative. If the person is mono-ocular, then the component cannot be assessed.
3. If the patient has bilateral fixed or unreactive pupils, then this component cannot be assessed.

*Zone Open-Globe* (location of the most posterior full-thickness aspect of the globe opening); *Closed-Globe* (based upon the anatomic location of the injury) I isolated to cornea (including the corneoscleral limbus) external (limited to bulbar conjunctiva, sclera, cornea) II corneoscleral limbus to a point 5 mm posterior into the sclera anterior segment III posterior to the anterior 5 mm of the sclera posterior segment.
Where:
- The anterior segment involves structures in the anterior segment internal to the cornea and including the posterior capsule, as well as the pars plicata but not the pars plana.
- The posterior segment includes all internal structures posterior to the posterior lens capsule (152).

**Treatment**

Treatment for ocular injuries and vision loss will vary depending on the type of damage, the cause of the damage, and whether it is physical or nerve related (149). Once the initial assessment is complete, the emergency treatment team will develop a treatment plan that best meets the specific needs of the patient. In some instances, the patient will require immediate treatment to mitigate any damage that is posing a significant risk to the viability of the eye or the patient’s vision (147). In other instances, treatment may be delayed so that the practitioners can ensure that the patient is stabilized (145).

Open globe injuries pose a significant threat and must be treated immediately. Therefore an initial examination must be used to identify and determine whether the injury is open or closed globe (149). The following is a list of common signs of open globe injury (150):
- Penetrating lid injury
- Bullous subconjunctival hemorrhage
- Shallow anterior chamber (AC)
- Blood in the AC (hyphema)
- Peaked pupil
- Iris disinsertion (iridodialysis)
- Lens dislocation
- Vitreous hemorrhage (Loss of red reflex can indicate vitreous hemorrhage or retinal detachment)
- The presence of an intraocular foreign body (IOFB)
Due to the extent of an open globe injury and the immediate risk to the patient, these injuries are typically treated immediately. Immediate treatment increases the chances of saving the eye and possibly restoring vision (148). However, the specific treatment for open globe injuries will vary based in a number of factors, including the potential risk to the patient, the type of damage, the risk of different treatments, and other factors specific to the individual patient’s case (149). The management and treatment of ocular trauma is very complex and must be determined based on each patient’s needs and their trauma status. In many instances, the initial treatment for open globe injuries will be to repair the wound while delaying secondary reconstruction, which may not occur for a number of days or weeks (146). However, there are advantages and disadvantages to closing the wound immediately during the emergency treatment phase.

The advantages of closing the wound immediately are listed below (150):

1. Most surgically trained ophthalmologists should be able to perform the procedure.
2. Primary wound closure reduces the risk of intraoperative bleeding, allowing time for the primary wound to heal and the corneal opacities to clear, when present.
3. Primary wound closure might allow time for the development of vitreous separation that would facilitate vitrectomy.
4. Primary wound closure allows a better evaluation of the eye’s condition postoperatively; this evaluation can be done using ultrasonography. Primary wound closure allows the ophthalmologist the opportunity to consult experts with subspecialty training; such consultations may be necessary for secondary repair.

In some instances, practitioners will delay immediately closing the wound in favor of a comprehensive approach that will address the various concerns relating to the traumatized eye. The advantages of delaying wound closure and following comprehensive management of the traumatized eye are as follows (150):
1. Comprehensive management is less expensive.
2. Comprehensive management offers potential prevention of endophthalmitis by removing the inoculated media.
3. Comprehensive management offers the potential reduction of post-injury inflammation and the prevention of scar tissue formation, such as proliferative vitreoretinopathy (PVR), again by removing stimulating factors (cytokines) present in the vitreous cavity.
4. Comprehensive management offers earlier visual rehabilitation.

The treatment of ocular injuries and subsequent vision loss is complex and often requires a multi-faceted approach. It is important that a patient be assessed for ocular damage and vision loss during the initial intake and assessment. However, depending on the severity of the damage and the potential for further complications, treatment may be delayed until the patient is stabilized. The goal with treatment for ocular injuries and vision loss is to repair any damage, minimize further damage, and restore vision (if possible). The emergency treatment team will assess the patient and provide individualized care depending on the needs of the patient.

**Loss of Hearing**

Hearing loss affects more than 250 million people worldwide (153). While a majority of the cases of hearing loss are congenital, meaning the loss was present at birth or shortly thereafter, a significant number of cases are acquired (154). Acquired hearing loss can be caused by a number of different factors, including aging, illness, and acoustic trauma (154). However, one of the primary causes of hearing loss is trauma related.

Typically, trauma related hearing loss is caused by assaults, motor vehicle accidents, industrial accidents, blast trauma, and sports injuries, as well as any accident that causes trauma to the head (155). In these instances, hearing loss
will be a result of direct trauma to the ear or as the result of nerve damage caused by head trauma or a traumatic brain injury (154). In instances where the loss is caused by direct trauma to the ear, the patient often experiences a fracture of the external auditory canal, tympanic membrane, perforation, fracture to the ossicular chains, fracture of the temporal bone, damage to the cochlea or the facial nerve (156).

Hearing loss is especially common in polytrauma situations as significant impacts and blasts are common causes of hearing loss. Trauma related hearing loss can be either temporary or permanent depending on the cause of the loss, the type of loss and the severity of damage (155). Typically, hearing loss is not immediately recognized, as the patient is often unconscious or “out of sorts” and cannot accurately communicate hearing difficulty (1).

The initial assessment and treatment stage is intended to address any severe or life threatening injuries, with additional assessments conducted once the patient is stabilized. Therefore, hearing loss is often identified after the initial assessment (153). Treatment will vary depending on the circumstances and the patient’s needs.

*Types of hearing loss*

There are four types of hearing loss, which are classified based on the anatomic location of the problem, which is the site of the lesion on either the middle or inner ear:

- Conductive
- Sensory
- Neural
- Mixed Hearing Loss

The following table provides information regarding the different types of hearing loss and the definitions and characterizations for each:
<table>
<thead>
<tr>
<th>Type of Loss</th>
<th>Causes and Impact on the Ear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductive</td>
<td>Conductive hearing loss is characterized by an obstruction to air conduction that prevents the proper transmission of sound waves through the external auditory canal and/or the middle ear. It is marked by an almost equal loss of all frequencies. The auricle (pinna), external acoustic canal, tympanic membrane, or bones of the middle ear may be dysfunctional. Conductive hearing loss may be congenital or caused by trauma, severe otitis media, otosclerosis, neoplasms, or atresia of the ear canal. Some conductive hearing loss can be treated surgically with tympanoplasty or stapedectomy, and the use of hearing aids and assistive listening devices may also be beneficial.</td>
</tr>
<tr>
<td>Sensorineural</td>
<td>Sensorineural hearing loss occurs when the sensory receptors of the inner ear are dysfunctional. Sensorineural deafness is a lack of sound perception caused by a defect in the cochlea and/or the auditory division of the vestibulocochlear nerve. This type of hearing loss is more common than conductive hearing loss and is typically irreversible. It tends to be unevenly distributed, with greater loss at higher frequencies. Sensorineural hearing loss may result from congenital malformation of the inner ear, intense noise, trauma, viral infections, ototoxic drugs (e.g., cisplatin, salicylates, loop diuretics), fractures of the temporal bone, meningitis, mènière's disease, cochlear otosclerosis, aging (i.e., presbycusis), or genetic predisposition, either alone or in combination with environmental factors. Many patients with sensorineural hearing loss can be habilitated or rehabilitated with the use of hearing aids. Patients with profound bilateral sensorineural hearing loss (e.g., at least 90 dB) who derive no benefit from conventional hearing aids may be appropriate candidates for the cochlear implant device, which bypasses the damaged structures of the cochlea and stimulates the function of the auditory nerve. Auditory brainstem implants, which are similar to multichannel cochlear implants, are used in patients with neurofibromatosis type 2 following vestibular schwannoma removal, especially those individuals who have lost integrity of the auditory nerves.</td>
</tr>
<tr>
<td>Auditory Neuropathy (AN)</td>
<td>Auditory Neuropathy (AN) is a type of sensorineural hearing loss that can be congenital or acquired. Unlike other types of sensorineural hearing loss where both Otoacoustic Emissions (OAE) and Auditory Brainstem Response (ABR) tests are likely to be abnormal, Auditory Neuropathy is characterized by normal OAE results and significantly abnormal ABR responses, even when measured with very loud sounds. The combination of normal OAE responses and severely impaired ABR responses is thought to reflect normal outer hair cell (OHC) function in the cochlea and abnormal auditory nerve function. The site of lesion for AN is often unknown, but possibilities include cochlear inner hair cells, cochlear spiral ganglia, synapse and/or eighth nerve fiber disorders. Audiograms of children with AN vary from</td>
</tr>
</tbody>
</table>
hearing in the normal range with complaints of difficulty hearing in background noise to profound hearing loss.

Mixed Hearing Loss
Individuallys with mixed hearing loss have both conductive and sensory dysfunction. Mixed hearing loss is due to disorders that can affect the middle and inner ear simultaneously, such as otosclerosis involving the ossicles and the cochlea, head trauma, middle ear tumors, and some inner ear malformations. Trauma resulting in temporal bone fractures may be associated with conductive, sensorineural, and mixed hearing loss.

In addition to the categories of hearing loss, the loss will be labeled based upon whether it affects one or both ears. A loss in one ear is considered a unilateral loss, and a loss in both ears is labeled as a bilateral loss (157). The degree, or severity, of the loss can vary and may be different for each ear. If the loss is the same in each ear, it is labeled symmetrical hearing loss. If the loss is different in each ear, it is considered asymmetrical hearing loss (158).

Degrees of Hearing Loss
Hearing loss is scaled based upon the severity of the loss. Practitioners rate the severity of the loss using five distinct categories that are based upon decibels. These categories are referred to as degrees of hearing loss and range from normal to profound hearing loss (155). The table below provides the different degrees of hearing loss, along with the numbers used to indicate the softest intensity that sound delivered in decibels is perceived by an individual tested with pure tone air conduction testing.

<table>
<thead>
<tr>
<th>Degree of Hearing Loss</th>
<th>Decibels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Hearing</td>
<td>-10 to 15 dB HL</td>
</tr>
<tr>
<td>Slight Hearing Loss</td>
<td>16-25 dB HL</td>
</tr>
<tr>
<td>Mild Hearing Loss</td>
<td>26-40 dB HL</td>
</tr>
<tr>
<td>Moderate Hearing Loss</td>
<td>41-55 dB HL</td>
</tr>
<tr>
<td>Moderate-Severe Hearing Loss</td>
<td>56-70 dB HL</td>
</tr>
<tr>
<td>Severe Hearing Loss</td>
<td>71-90 dB HL</td>
</tr>
<tr>
<td>Profound Hearing Loss</td>
<td>&gt;90 dB HL</td>
</tr>
</tbody>
</table>

(153)
Hearing loss is assessed using three categories: type, degree, and configuration. The configuration of hearing loss is categorized in four different configurations. The following are the four configurations of hearing loss:

- Flat: thresholds essentially equal across test frequencies.
- Sloping: lower (better) thresholds in low-frequency regions and higher (poorer) thresholds in high-frequency regions.
- Rising: higher (poorer) thresholds in low-frequency regions and lower (better) thresholds in higher-frequency regions.
- Trough-shaped ("cookie-bite" or "U" shaped): greatest hearing loss in the mid-frequency range, with lower (better) thresholds in low- and high-frequency regions.

Assessment and Treatment

The first stage of treating hearing loss is assessing the extent of loss and the type. Practitioners will use a variety of tests to assess hearing loss. Typically, a hearing loss assessment will include a battery of audiologic tests, with the specific tests and measures selected according to the age of the patient. In addition, a general hearing assessment will include a hearing history, physiological procedures, and behavioral procedures. In polytrauma situations, the assessment differs slightly in that it does not typically include a hearing history as it is assumed that the injury is new. Therefore, polytrauma hearing loss assessments typically involve only the physiological and behavioral procedures.

The following table provides information on the various types of assessments used to determine hearing loss, with an explanation of each:

<table>
<thead>
<tr>
<th>Type of Assessment</th>
<th>Explanation and Specific Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physiological procedures or acoustic admittance measurements</td>
<td>Otoacoustic emissions (OAE). OAE are low-level sounds produced by the sensory hair cells of the cochlea (primarily the outer hair cells of the inner ear) as part of the normal hearing process. Hair cells that are normally functioning emit acoustic energy, which can be...</td>
</tr>
</tbody>
</table>
| **Behavioral audiometry testing** | recorded by placing a small probe (containing a microphone) attached to a soft ear tip in the external ear canal opening. The earphone delivers test signals into the ear canal that evoke an acoustic response from the hair cells, and the responses are recorded by a second microphone in the probe. These responses are called evoked otoacoustic emissions (EOAE).

**Auditory brainstem response (ABR)**
Using clicks or tones, this test can estimate hearing threshold sensitivity and determine the integrity of the auditory pathway from the cochlea to the level of the brainstem. Small disc electrodes are pasted on the scalp, and repetitive stimuli are delivered by an earphone. The auditory potentials (electrical/neural activity generated by the auditory nerve and brainstem) that are evoked by the repetitive stimuli are then recorded by a computer.

**Middle ear muscle reflexes**
Involuntary middle-ear muscle reflexes to sounds, usually elicited by moderately loud tones or noises, are recorded.

**Tympanometry**
This procedure is used to assess the function of the middle ear by placing a small probe attached to a soft, plastic ear tip at the ear canal opening and varying the air pressure released into the ear canal. Tympanometry is not a hearing test.

The goal of behavioral audiometric testing is to obtain a valid measure of hearing threshold sensitivity for each ear in the speech-frequency range, ideally from 250 through 8,000 Hz. Results of the audiometric assessment are displayed on an audiogram. Behavioral audiometric tests are used to:

- Determine whether or not a patient has a hearing loss.
- Determine the degree, configuration, and type of hearing loss if hearing loss does exist.
- Monitor the patient's hearing over time.
- Provide information for the fitting of hearing aids or other sensory devices.
- Help determine the functional benefit of hearing aids or other sensory devices.

Once the type and severity of hearing loss has been identified, the emergency treatment team will make a determination regarding treatment. The specific treatment used will depend on the type of hearing loss, the severity of the loss.
and the impact to the ear. In some instances, treatment will be delayed until the patient has recovered from the other injuries (159). When this occurs, treatment will often be long term, rehabilitative care that is delivered in an outpatient capacity (153).

Common treatment for hearing loss includes working with a speech therapist to maintain speaking abilities (160). Other treatment may include the use of hearing aids. Hearing aids are only used when a patient has some level of hearing (158). In many instances, the hearing loss will be complete and permanent, which will prevent the patient from receiving any form of rehabilitative treatment (155). When this occurs, treatment will only involve providing immediate medical care for any direct injury to the ear. This treatment is intended to repair initial damage while preventing any further damage (157).

**Blast Trauma, Otologic Injury and Hearing Loss**

Hearing loss and otologic injury that occurs as the result of blast trauma is discussed separately as the unique attributes of the trauma warrant special attention. Ear injury is typically the first injury to occur during a blast (161). During a blast, injury frequently occurs in the structures of the middle and inner ear (156). These represent the most common type of injury after a blast. Blast injury to the ear may result in symptoms of tinnitus, earache, hearing loss, or vertigo (155). While ear injury is one of the first injuries to occur during a blast, is often one of the last injuries to diagnose (153). Due to the need to diagnose and treat life-threatening injuries, otologic injury and hearing viability are typically assessed once the patient is stable.

According to the Center for Disease Control Fact Sheet on Ear Blast Injuries, the following are the clinical presentations of blast injury to the ear (156):

- **External Ear**
  - *Injury to the external ear is caused most often by flying debris (secondary blast injury)*
• Degloving of the cartilage may occur; considered to be a serious injury

Tympanic Membrane (TM)
• The TM is exquisitely sensitive to variations of atmospheric pressure as it functions to transmit minute pressure oscillations encountered by impulsive and continuous sound waves
• Blast overpressure enters the external auditory canal, stretching and displacing the TM medially
• A spectrum of injury may be seen, ranging from intra-tympanic hemorrhage in minor cases to total tympanic membrane perforation in powerful blasts
• Perforations may be unilateral or bilateral, small or complete, and single or double
• The shape of the laceration may be smooth and linear, punched out, or ragged with the edges inverted or everted

Middle Ear
• Disruption of the ossicular chain may occur, especially in larger blasts
• Cholesteatoma within the middle ear and mastoid cavity may occur and are potentially destructive lesions that can erode and destroy important structures of the middle ear, temporal bone, and skull base
• Sequelae of disease can cause conductive and sensorineural hearing loss, vestibular disturbances, cranial nerve palsy, as well as central nervous system complications such as brain abscess and meningitis, making the injury potentially fatal

Inner Ear
• Damage to the auditory and vestibular components of the inner ear may also occur
• The typical blast-injured patient will experience a temporary hearing threshold change; most regain hearing within hours, for others resolution may take days to weeks.
The treatment for blast trauma related ear injury and hearing loss often differ from treatment for other trauma related hearing loss due to the nature of the injury. In most trauma related hearing loss, there is little to no tissue damage. However, with blast trauma related injury, there is often significant tissue damage that warrants additional treatment beyond the standard treatment for hearing loss (161).

The Center for Disease Control provides the following guidelines for the treatment of blast related ear injury and hearing loss (156):

Treatment of External Ear Injuries
- Manage as other soft tissue injuries with attention to foreign body removal, cleaning and irrigation of wounds, and closure
- Cartilage must not be left exposed; wounds should be closed primarily; if the cartilage of the pinna is degloved, it should be buried in the post auricular pouch (may require the expertise of an otolaryngologist or a plastic surgeon)

Treatment of Tympanic Membrane Rupture
- Treatment of TM perforations is typically expectant; if cerumen or blood clots obscure view of the eardrum, these can be carefully suctioned and cleaned by an otolaryngologist
- The ear should be kept clean and dry, and the patient should be referred to a specialist
- Antibiotic eardrops to irrigate and clear the ear of debris or blood clots are indicated for TM perforations or ear canal lacerations

Treatment of Middle and Inner Ear Injuries
- Treatment for middle and inner ear injuries typically can be deferred until an otolaryngologist is available
- Baseline audiometry in all blast-injured patients has been advocated because hearing deficits are common and not always noted by the patient;
patients should be followed with interval audiometric evaluation to follow progress during recovery

Disposition

- **TM perforations typically have an excellent prognosis with spontaneous resolution in the majority of cases**
- **For irregular perforations with everted flap, realignment may improve chances of healing; perforations resolve most frequently in the first three months after injury**
- **Tympanoplasty is indicated if spontaneous resolution is not observed after close observation**
- **Any TM perforation runs the risk of cholesteatoma formation, especially those perforations that are larger and do not resolve; follow-up is indicated biannually for a minimum of two years.**

Due to the extent and severity of blast related ear injury and subsequent hearing loss, it is imperative that any reparative treatment is performed as quickly as possible to prevent further damage and increase the probability that the patient’s hearing may be restored (153). In some instances, the patient will make a complete recovery and will not suffer any long-term hearing loss (161). However, in other instances, the damage will be too severe to fully repair (156). While initial damage may be repaired and further damage prevented, many patients will not be able to regain hearing. Long term, or permanent, hearing loss is a common result of blast trauma (155).

**EMERGENCY TREATMENT**

The first component of treatment for polytrauma is emergency treatment. Due to the severity of the trauma and the presence of potentially life threatening injuries, it is imperative that patients be treated immediately. Typically, patients are
transported to the emergency room, where a team of medical providers comprised of emergency personnel, nurses, surgeons, physicians and any appropriate and relevant specialists, will treat them. During the initial stage of emergency treatment, the highest priority is directed toward diagnosis and treatment of life-threatening injuries (162). When a patient arrives, the treatment team will identify those injuries that are most severe and life threatening and immediately begin to treat them. The goal is to be able to stabilize the patient so that treatment can begin on all other injuries (163).

While the treatment that begins in the emergency room is often considered the first stage of emergency treatment, it is actually the treatment that the patient receives prior to arriving at the hospital that constitutes the primary stage of trauma treatment (8). However, since this treatment is limited to emergency responders, it is not focused on injury treatment and patient stabilization (39). Rather, pre-hospital care, also known as field triage, involves basic life saving or life sustaining measures that will prevent the patient from succumbing to the injuries prior to arriving at the hospital (163). Therefore, pre-hospital treatment is limited to addressing only life-threatening injuries in the field through control of bleeding, cervical-spine stabilization, and similar interventions (162). Emergency responders receive training specific to trauma situations and are well equipped to provide the care listed above (39).

As part of the field triage process, emergency responders will be expected to make a determination regarding the type of treatment center the patient should be transported to.

The Center for Disease Control provides the following information regarding on-scene triage (164):

At the scene of an injury, Emergency Medical Service (EMS) professionals must identify the severity and type of injury, and determine which hospital
or other facility would be the most appropriate to meet the needs of the patient.

The profound importance of daily on-scene triage decisions made by EMS professionals is reinforced by CDC-supported research that shows that the overall risk of death was 25 percent lower when care was provided at a Level I trauma center than when it was provided at a non-trauma center.

Not all injured patients can or should be transported to a Level I trauma center. Other hospitals can effectively meet the needs of patients with less severe injuries, and may be closer to the scene. Transporting all injured patients to Level I centers—regardless of injury severity—limits the availability of Level I trauma center for those patients who really need the level of care provided at those facilities. Proper field triage ensures that patients are transported to the most appropriate healthcare facility that best matches their level of need.

The following link is for a decision scheme poster that is used to determine where to bring a patient during field triage:


Once a patient arrives at the hospital or trauma center, the emergency treatment team takes over and begins to work on stabilizing the patient through the treatment of any life threatening injuries. In many instances of polytrauma, the outcome is fatal (9). Therefore, the primary goal in the initial emergency treatment phase is to treat any life threatening injuries and prevent a fatal outcome.

Many polytrauma patients die within the first hour after an accident due to head trauma or severe hemorrhage (1). If a patient survives the first hour, there is still an increased risk of fatality within the first few hours due to airway, breathing, cardiovascular issues and internal damage (9). When discussing stabilization of
the trauma patient, clinicians refer to the first “golden hour” for the initial resuscitative techniques (162). Due to the increased risk of death within the first few hours after the trauma occurs, it is imperative that the patient receives the appropriate care and treatment.

When a patient transitions from the pre-hospital stage to the emergency room stage of treatment, the care of the patient transitions from an initial, basic maintenance stage to a more definitive treatment stage (163). In some instances, the patient will only be in the emergency department for a brief period of time. In others, the patient will spend hours in the emergency room undergoing multiple tests and treatment protocols (1).

**Recommended staffing per patient**

Once a patient enters the emergency room, the emergency treatment team will take over the assessment and treatment of the patient (165). Therefore, it is necessary that the emergency team be adequately staffed. The care and treatment of a severely injured trauma patient is a coordinated team effort that involves the allocation of tasks that are often conducted simultaneously (162). Typical team composition includes a trauma surgeon (who often leads the team) or an emergency medicine trained physician. In addition, physicians, nurses and the appropriate technical staff will work alongside the rest of the team to treat immediate, life-threatening injuries (8).

**Evaluation and Assessment**

As soon as an individual enters the emergency department, and often during the pre-hospital stage of treatment, the emergency treatment team will begin evaluating the patient and assessing the polytrauma. There are a number of initial assessments, diagnostic tests and evaluations that the treatment team will use to determine the status of the patient, the extent of the injuries, the type of injuries, the underlying affects of the trauma and the specific needs of the patient (166). While all of these tests and assessments are important in the initial stages.
of response and treatment, there are some that should be conducted immediately while others can be postponed until the patient is stabilized (162).

**ABCDE Approach**

The first step in the evaluation and assessment of the polytrauma patient is the Airway, Breathing, Circulation, Disability, Exposure (ABCDE) approach. This approach can be used in any type of clinical emergency to assess the patient and determine the necessary treatment needs (8). Using the ABCDE approach is highly recommended by most medical professionals as it is considered an effective means of improving patient outcomes through the early identification and treatment of life threatening injuries and complications (167).

Skilled professionals in an acute setting best use the ABCDE approach, as it requires a basic understanding and common knowledge of early identification and treatment (162). If a team is providing the treatment, it is important that all team members understand and employ the ABCDE approach to ensure consistent assessment and consistent identification and treatment (167). Emergency personnel and treatment team members should receive adequate training in the ABCDE approach prior to working with trauma patients.

The goals of the ABCDE approach include the following (167):

- to provide life-saving treatment
- to break down complex clinical situations into more manageable parts
- to serve as an assessment and treatment algorithm
- to establish common situational awareness among all treatment providers
- to buy time to establish a final diagnosis and treatment.

The ABCDE approach is promoted as an effective tool for diagnosing and treating critically ill or injured patients and is widely used in emergency care setting. The ABCDE approach is most often utilized by: emergency technicians, critical care specialists, and traumatologists (166). Using the ABCDE approach
in conjunction with other emergency treatment protocol has proven to increase the patient survival rate and decrease the long-term impact of the injuries (168).

The ABCDE approach can be used with all patients, regardless of age or medical status. Regardless of the cause, the clinical signs of various critical conditions are similar. Therefore, the ABCDE approach can be used to identify clinical issues even if the cause is unknown. In fact, it is not necessary for emergency personnel to know the underlying cause of the conditions when initiating ABCDE (162). Ultimately, the ABCDE approach should be used in any situation in which a critical injury is present, as it is a useful tool for determining the presence of critical conditions, especially when those conditions are not immediately apparent or identifiable (166).

The ABCDE approach provides efficiency in the identification and treatment of the patient as the initial assessment and the treatment are performed in conjunction with each other (167). In a situation where the cause is not apparent, immediate treatment may be necessary for any life threatening injuries or conditions. In these instances, treatment will be initiated prior to making a definitive diagnosis. The ABCDE approach provides a means for initiating treatment without knowing the exact diagnosis (162).

The ABCDE approach follows a standard process that follows the words indicated by the ABCDE. First, life-threatening airway problems are assessed and treated; second, life threatening breathing problems are assessed and treated, etc. This approach enables the treatment team to quickly identify issues and to treat them accordingly. The ABCDE approach also helps determine which services are needed and what level of assistance is required.

In many emergency situations, additional care may be needed from other emergency responders, specialists, and other hospital departments. The ABCDE approach helps quickly determine the level of assistance required and
the specific departments that are needed for treatment and assistance (163). This identification helps increase the speed and efficiency of treatment, thereby improving the outcome.

The ABCDE assessment should be conducted as soon as possible to begin the treatment process (166). In addition, the assessment should be repeated in regular intervals until the patient is stable as a means of determining the effectiveness of various treatments (165). If a patient shows signs of deterioration, additional treatment may be needed. The patient should be reassessed after each treatment or intervention to assess the outcome (163).

The following is the description and recommendation for using the ABCDE approach with patients:

A – Airway: is the airway patent?

If the patient responds in a normal voice, then the airway is patent. Airway obstruction can be partial or complete. Signs of a partially obstructed airway include a changed voice, noisy breathing (e.g., stridor), and an increased breathing effort. With a completely obstructed airway, there is no respiration despite great effort (i.e., paradox respiration, or “see-saw” sign). A reduced level of consciousness is a common cause of airway obstruction, partial or complete. A common sign of partial airway obstruction in the unconscious state is snoring.

Untreated airway obstruction can rapidly lead to cardiac arrest. All health care professionals, regardless of the setting, can assess the airway as described and use a head-tilt and chin-lift maneuver to open the airway. With the proper equipment, suction of the airways to remove obstructions, for example, blood or vomit, is recommended. If possible, foreign bodies causing airway obstruction should be removed. In the event of a complete airway obstruction, treatment should be given according to current guidelines. In brief, to conscious patients give five back blows alternating
with five abdominal thrusts until the obstruction is relieved. If the victim becomes unconscious, call for help and start cardiopulmonary resuscitation according to guidelines.

Importantly, high-flow oxygen should be provided to all critically ill persons as soon as possible.

B – Breathing: is the breathing sufficient?
In all settings, it is possible to determine the respiratory rate, inspect movements of the thoracic wall for symmetry and use of auxiliary respiratory muscles, and percuss the chest for unilateral dullness or resonance. Cyanosis, distended neck veins, and lateralization of the trachea can be identified. If a stethoscope is available, lung auscultation should be performed and, if possible, a pulse oximeter should be applied.

Tension pneumothorax must be relieved immediately by inserting a cannula where the second intercostal space crosses the midclavicular line (needle thoracocentesis). Bronchospasm should be treated with inhalations.

If breathing is insufficient, assisted ventilation must be performed by giving rescue breaths with or without a barrier device. Trained personnel should use a bag mask if available.

C – Circulation: is the circulation sufficient?
The capillary refill time and pulse rate can be assessed in any setting. Inspection of the skin gives clues to circulatory problems. Color changes, sweating, and a decreased level of consciousness are signs of decreased perfusion. If a stethoscope is available, heart auscultation should be performed. Electrocardiography monitoring and blood pressure measurements should also be performed as soon as possible.
Hypotension is an important adverse clinical sign. The effects of hypovolemia can be alleviated by placing the patient in the supine position and elevating the patient’s legs. An intravenous access should be obtained as soon as possible and saline should be infused.

D – Disability: what is the level of consciousness?
The level of consciousness can be rapidly assessed using the AVPU method, where the patient is graded as alert (A), voice responsive (V), pain responsive (P), or unresponsive (U). Alternatively, the Glasgow Coma Score can be used.16 Limb movements should be inspected to evaluate potential signs of lateralization. The best immediate treatment for patients with a primary cerebral condition is stabilization of the airway, breathing, and circulation. In particular, when the patient is only pain responsive or unresponsive, airway patency must be ensured, by placing the patient in the recovery position, and summoning personnel qualified to secure the airway. Ultimately, intubation may be required. Pupillary light reflexes should be evaluated and blood glucose measured. A decreased level of consciousness due to low blood glucose can be corrected quickly with oral or infused glucose.

E – Exposure: any clues to explain the patient’s condition?
Signs of trauma, bleeding, skin reactions (rashes), needle marks, etc, must be observed. Bearing the dignity of the patient in mind, clothing should be removed to allow a thorough physical examination to be performed. Body temperature can be estimated by feeling the skin or using a thermometer when available (167).

The following table provides information regarding the ABCDE method and specific treatments for each category:
<table>
<thead>
<tr>
<th>A – Airways</th>
<th>Assessment</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voice</td>
<td>Head tilt and chin lift</td>
<td></td>
</tr>
<tr>
<td>Breath sounds</td>
<td>Oxygen (15 l min⁻¹) Suction</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B – Breathing</th>
<th>Assessment</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory rate (12–20 min⁻¹)</td>
<td>Seat comfortably</td>
<td></td>
</tr>
<tr>
<td>Chest wall movements</td>
<td>Rescue breaths</td>
<td></td>
</tr>
<tr>
<td>Chest percussion</td>
<td>Inhaled medications</td>
<td></td>
</tr>
<tr>
<td>Lung auscultation</td>
<td>Bag-mask ventilation</td>
<td></td>
</tr>
<tr>
<td>Pulse oximetry (97%–100%)</td>
<td>Decompress tension pneumothorax</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C – Circulation</th>
<th>Assessment</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin color, sweating</td>
<td>Stop bleeding</td>
<td></td>
</tr>
<tr>
<td>Capillary refill time (&lt;2 s)</td>
<td>Elevate legs</td>
<td></td>
</tr>
<tr>
<td>Palpate pulse rate (60–100 min⁻¹)</td>
<td>Intravenous access</td>
<td></td>
</tr>
<tr>
<td>Heart auscultation</td>
<td>Infuse saline</td>
<td></td>
</tr>
<tr>
<td>Blood pressure (systolic 100–140 mmHg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrocardiography monitoring</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>D – Disability</th>
<th>Assessment</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level of consciousness – AVPU</td>
<td>Treat Airway, Breathing, and Circulation problems</td>
<td></td>
</tr>
<tr>
<td>Alert</td>
<td>Recovery position</td>
<td></td>
</tr>
<tr>
<td>Voice responsive</td>
<td>Glucose for hypoglycemia</td>
<td></td>
</tr>
<tr>
<td>Pain responsive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unresponsive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limb movements</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pupillary light reflexes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood glucose</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>E – Exposure</th>
<th>Assessment</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expose skin</td>
<td>Treat suspected cause</td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(167)

**Scoring the Trauma**

Once the initial ABCDE assessment is complete and any immediate, life-threatening injuries have been identified, the emergency treatment team will score the trauma (169). In some instances, scoring is completed in conjunction with the initial ABCDE assessment. However, it is more common for the trauma to be scored after the ABCDE assessment has been completed (167). There are a number of different scoring systems that can be used at this point. Depending on the type of trauma, the available resources and the preferences of the treatment team, one or more of the following assessments may be used:

- AIS: Abbreviated Injury Scale
- ISS: Injury Severity Score
- NISS: New Injury Severity Score
- ICISS: International Classification of Diseases Injury Severity Score (ICISS)
- TS: Trauma Score
- TI: Triage Index
- PI: prognostic Index
- GCS: Glasgow Coma Scale
- RTS: Revised Trauma Score
- CRAMS Scale
- APACHE I-II-III
- Trauma Index
- TRISS: Trauma ISS
- ASCOT: Severity Characterization of Trauma
- HARM: Harborview Assessment of Risk of Mortality

Of the scoring systems listed above, the following descriptions are provided for the most common and most widely used.

**Abbreviated Injury Scale:**

The Abbreviated Injury Scale (AIS) is an anatomical scoring system first introduced in 1969. Since this time it has been revised and updated so that it now provides a reasonably accurate ranking of the severity of injury. The latest incarnation of the AIS score is the 1998 revision. A scaling committee of the Association monitors the AIS for the Advancement of Automotive Medicine.

Injuries are ranked on a scale of 1 to 6, with 1 being minor, 5 severe, and 6 a nonsurvivable injury. This represents the ‘threat to life’ associated with an injury and is not meant to represent a comprehensive measure of severity. The AIS is not an injury scale, in that the difference between AIS1 and AIS2 is not the same as that between AIS4 and AIS5. There are many similarities between the AIS scale and the Organ Injury Scales of the AAST.
Injury Severity Score (ISS) & New Injury Severity Score (NISS):

The Injury Severity Score (ISS) is an anatomical scoring system that provides an overall score for patients with multiple injuries. Each injury is assigned an AIS and is allocated to one of six body regions (Head, Face, Chest, Abdomen, Extremities (including Pelvis), External). Only the highest AIS score in each body region is used. The 3 most severely injured body regions have their score squared and added together to produce the ISS score.

<table>
<thead>
<tr>
<th>Region</th>
<th>Injury Description</th>
<th>AIS</th>
<th>Square Top Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head &amp; Neck</td>
<td>Cerebral Contusion</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Face</td>
<td>No Injury</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Chest</td>
<td>Flail Chest</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>Abdomen</td>
<td>Minor Contusion of Liver Complex Rupture Spleen</td>
<td>2 5</td>
<td>25</td>
</tr>
<tr>
<td>Extremity</td>
<td>Fractured femur</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>External</td>
<td>No Injury</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

**Injury Severity Score:** 50

The ISS score takes values from 0 to 75. If an injury is assigned an AIS of 6 (unsurvivable injury), the ISS score is automatically assigned to 75. The ISS score is virtually the only anatomical scoring system in use and correlates linearly with mortality, morbidity, hospital stay and other measures of severity. Its weaknesses are that any error in AIS scoring increases the ISS error.
Many different injury patterns can yield the same ISS score and injuries to different body regions are not weighted. Also, as a full description of patient injuries is not known prior to full investigation & operation, the ISS (along with other anatomical scoring systems) is not useful as a triage tool.

As multiple injuries within the same body region are only assigned a single score, a proposed modification of the ISS, the "New Injury Severity Score" (NISS), has been proposed. This is calculated as the sum of the squares of the top three scores regardless of body region. The NISS has been found to statistically outperform the traditional ISS score (169).

**International Classification Of Diseases Injury Severity Score (ICISS):**

ICISS utilizes the ICD-9 codes assigned to each patient to calculate a severity of injury score. Measured survival risk ratios are assigned to all ICD-9 trauma codes. The simple product of all such ratios for an individual patient's injuries has been found to predict outcome more accurately than ISS.

\[
\text{ICISS} = (\text{SRR})_{\text{injury1}} \times (\text{SRR})_{\text{injury2}} \times (\text{SRR})_{\text{injury3}} \times (\text{SRR})_{\text{injury4}} \ldots
\]

ICISS is promoted as being able to be calculated from existing hospital information without the need for a dedicated trauma registrar. This assumes, however, that the non-clinical hospital coders are able to accurately interpret and document the injuries sustained (171).

**Revised Trauma Score:**

The Revised Trauma Score (RTS) is a physiological scoring system, with high inter-rater reliability and demonstrated accuracy in predicting death. It is scored from the first set of data obtained on the patient, and consists of Glasgow Coma Scale, Systolic Blood Pressure and Respiratory Rate.
<table>
<thead>
<tr>
<th>Glasgow Coma Scale (GCS)</th>
<th>Systolic Blood Pressure (SBP)</th>
<th>Respiratory Rate (RR)</th>
<th>Coded Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-15</td>
<td>&gt;89</td>
<td>10-29</td>
<td>4</td>
</tr>
<tr>
<td>9-12</td>
<td>76-89</td>
<td>&gt;29</td>
<td>3</td>
</tr>
<tr>
<td>6-8</td>
<td>50-75</td>
<td>6-9</td>
<td>2</td>
</tr>
<tr>
<td>4-5</td>
<td>1-49</td>
<td>1-5</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Values for the RTS are in the range 0 to 7.8408. The RTS is heavily weighted towards the Glasgow Coma Scale to compensate for major head injury without multisystem injury or major physiological changes. A threshold of RTS < 4 has been proposed to identify those patients who should be treated in a trauma center, although this value may be somewhat low (172).

**CRAMS Scale**:

The CRAMS Scale (Circulation, Respiration, Abdomen, Motor, Speech) measures five components and is intended to triage those patients requiring transport to a trauma center. It is intended to reduce the number of minor trauma cases referred to trauma centers.

**Parameters**:

1. systolic blood pressure or capillary refill
2. respirations
3. examination of trunk
4. motor
5. speech

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Finding</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>systolic blood pressure or capillary refill</td>
<td>blood pressure &gt;100 mm Hg, or normal capillary refill</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>85 ≤ blood pressure ≤ 100 mm Hg, or delayed capillary refill</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>blood pressure &lt;85 mm Hg, or no capillary refill</td>
<td>0</td>
</tr>
<tr>
<td>CRAMS Scale</td>
<td>Description</td>
<td>Score</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------</td>
<td>-------</td>
</tr>
<tr>
<td>respirations</td>
<td>normal</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>abnormal (labored and/or shallow)</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>absent</td>
<td>0</td>
</tr>
<tr>
<td>trunk</td>
<td>thorax and abdomen nontender</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>thorax or abdomen tender</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>rigid abdomen, flail chest, penetrating wound to chest, or penetrating wound to abdomen</td>
<td>0</td>
</tr>
<tr>
<td>motor</td>
<td>normal</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>responds only to pain</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>no response or decerebrate</td>
<td>0</td>
</tr>
<tr>
<td>speech</td>
<td>normal</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>confused</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>no intelligible words</td>
<td>0</td>
</tr>
</tbody>
</table>

CRAMS scale = (points for systolic blood pressure or capillary refill) + (points for respirations) + (points for trunk findings) + (points for motor response) + (points for speech)

**Interpretation:**
- maximum score (indicating least affected) : 10
- minimum score (indicating most affected) : 0
- score ≤ 8: major trauma (those who died in ED or who required emergency surgery)
- score ≥ 9: minor trauma

**Trauma and Injury Severity Score - (TRISS):**

The Trauma Score – Injury Severity Score (TRISS) determines the probability of survival (Ps) of a patient from the ISS and RTS using the following formula:

\[ Ps = \frac{1}{1 + e^{-b}} \]

`b` is calculated from: \[ b = b_0 + b_1(\text{RTS}) + b_2(\text{ISS}) + b_3 \text{(Age Index)} \].
The coefficients \( b_0 \)–\( b_3 \) (table below) are derived from multiple-regression analysis of the Major Trauma Outcome Study database.

The Age Index is 0 if the patient is below 54 years of age or 1 if 55 years and over.

The coefficients \( b_0 \)–\( b_3 \) are different for blunt and penetrating trauma.

If the patient is less than 15 years old, the blunt coefficients are used regardless of the actual mechanism of injury.

The coefficients \( b_0 \) - \( b_3 \) are derived from multiple regression analysis of the Major Trauma Outcome Study (MTOS) database. Age Index is 0 if the patient is below 54 years of age or 1 if 55 years and over. \( b_0 \) to \( b_3 \) are coefficients which are different for blunt and penetrating trauma. If the patient is less than 15, the blunt index for \( b_3 \) (Age) is used regardless of mechanism.

<table>
<thead>
<tr>
<th></th>
<th>Blunt</th>
<th>Penetrating</th>
</tr>
</thead>
<tbody>
<tr>
<td>( b_0 )</td>
<td>-0.4499</td>
<td>-2.5355</td>
</tr>
<tr>
<td>( b_1 )</td>
<td>0.8085</td>
<td>0.9934</td>
</tr>
<tr>
<td>( b_2 )</td>
<td>-0.0835</td>
<td>-0.0651</td>
</tr>
<tr>
<td>( b_3 )</td>
<td>-1.7430</td>
<td>-1.1360</td>
</tr>
</tbody>
</table>

The trauma scoring scales listed above are used to determine the level of severity of the trauma, the damage incurred, and whether the patient should be referred to a trauma center (166). Once the initial trauma scoring is complete, the emergency treatment team will begin to address the treatment needs of the patient. However, it is important to note that, due to the severity and immediacy of some of the injuries, some treatment will occur concurrently with the trauma scoring (175).

After the patient is assessed using the ABCDE assessment and one or more of the trauma scoring systems, evaluation shifts to individual body parts and
specific injuries (162). As the patient receives initial emergency treatment, the treatment team will determine the specific tests and patient evaluations that will be necessary to fully diagnose the patient’s injuries and develop a treatment plan. Some of these tests will be administered as the patient is receiving initial care. However, most tests will be delayed until the patient is stabilized (8).

**Trauma Series X-Ray**

It is important to have the patient undergo diagnostic X-rays as part of polytrauma assessment and treatment. It is important use diagnostic imaging with polytrauma patients, as the often have injuries that cannot be detected upon initial examination (9). Due to the extreme nature of polytrauma inducing accidents, it is likely that a patient will suffer a number of less apparent injuries to the body parts listed above. However, while these injuries may not be immediately apparent, it does not reduce the potential impact they can have on the patient’s overall recovery as well as the potential for survival.

The following X-rays are part of the Trauma Series X-ray:

- Cervical Spine
- Chest
- Pelvis

**Cervical Spine X-Ray:**

A cervical spine x-ray is used to identify any complications associated with neck pain (175). A cervical x-ray is commonly used when a patient presents with neck pain following a trauma situation of if the patient is experiencing chronic neck pain in conjunction with upper limb weakness, numbness or tingling (176). A cervical spine x-ray is commonly used to identify cervical vertebrae fractures (bone breaks), vertebral malalignment, dislocation and degenerative spine disease (177).
When a cervical spine x-ray is conducted as part of an emergency trauma situation, the images are interpreted immediately so that treatment can begin as soon as possible (178). Since the images are being interpreted in an emergency department, it is often an emergency doctor who interprets them (132). Most often, it will be an emergency physician, orthopedic surgeon, or general surgeon who is already involved in the care and treatment of the patient. If a radiologist is available, he or she will often be asked to interpret the images (177).

The following is a description of the process used to perform the cervical spine x-ray:

*Cervical Spine X-Ray (C-Spine X-Ray)* is performed by a radiographer in an X-Ray room. The standard three views taken are the AP (anteroposterior view, which looks at the spine from the front); lateral (which looks at the spine from the side) and peg view (this looks at the upper part of the cervical spine and requires the patient to open the mouth wide). The 5-series also includes flexion and extension views. X-Rays are taken with the patient’s head in full flexion (leaning as far forward as possible). The patient will be asked to bend the head forward as far as possible, and to extend the neck backwards as far as possible. (179)

Chest X-Ray:
Chest X-rays are used in trauma situations to provide initial evaluations of blunt and penetrating trauma to the chest (180). The images are used in conjunction with other assessments to identify any injuries and provide the appropriate treatment. There are a range of injuries that can occur in the chest and upper abdomen as the result of trauma, and the use of chest x-rays is an important step in the assessment and treatment process. However, it is important that emergency treatment personnel are familiar with the various injuries that can
occur in these regions for accurate interpretation and the development of effective treatment recommendations (181).

It is ideal to obtain chest x-rays in the posteroanterior and lateral views with the patient sitting upright and in full inspiration (182). However, trauma patients are often unable to be placed in this position. Therefore, trauma patients are often imaged in the supine position using single view anteroposterior radiographs (183). This can cause complications with injury visualization and localization, as these do not provide an appropriate angle to distinguish superimposed soft tissue and bone lesions from the underlying viscera (184). According to the American Journal of Roentgenology (185):

“Air–fluid levels are not visible because of the perpendicular orientation of the x-ray beam. Poor inspiratory effort and magnification effects can produce pseudocardiomegaly and apparent increases in pulmonary vascularity. Nevertheless, when analyzed with respect to these limitations, the chest radiograph can be an invaluable tool that provides a wide spectrum of information regarding a number of organ systems.”

When using an anteroposterior chest radiograph as the initial evaluation of chest trauma, the following guidelines should be used, as the techniques will differ depending on whether the patient has had a blunt or penetrating trauma:

- **Blunt** -
  
  All blunt trauma patients should have a portable chest X-ray performed in the trauma resuscitation room. The chest X-ray is a rapid screening examination that will identify significant thoracic problems requiring intervention.

  Chest radiographs in blunt trauma patients are taken in the supine position, as unstable spinal fractures have not been ruled out at this stage. Chest films should be slightly over-penetrated to allow better visualization of the thoracic spine, paraspinal lines and aortic outline.
• Penetrating -

Patients with a stab wound that may have violated the thoracic cavity or mediastinum should have a chest X-ray. In practice, this means all patients with stab wounds between the neck and the umbilicus (front or back!).

For gunshot wounds, all patients with wounds between the neck and the pelvis/buttock area should have a chest film. This is especially true if the bullet track is unclear, and there is a missing bullet or an odd number of entry/exit wounds (181).

If possible, the chest-X-ray in penetrating trauma should be taken with the patient sitting upright. This will increase the sensitivity for detecting a small haemothorax, pneumothorax or diaphragm injury (186).

Pelvic X-Rays:

Pelvis X-rays are routinely used with polytrauma patients as a means to identify pelvic fractures that may have haemodynamic consequences (187). Pelvic X-rays for trauma patients are often conducted using a portable X-ray machine. Although the machine is portable and uses an AP view, it is considered a solid survey instrument that can be used to conduct an initial evaluation on the patient (188). The portable pelvic X-ray is used as a screening tool to determine if the patient has any fractures or other injuries to the pelvic area that may need to be treated (189). Specifically, the standard AP pelvic imaging is used for patients who have sustained high impact, blunt trauma, most often in multiple areas.

While the portable pelvic X-ray is a satisfactory tool for identifying initial trauma, the sensitivity is quite low and it cannot be used to determine if the pelvic area is stable or not (190). In fact, research shows that the accuracy of the portable, plain film pelvic imaging is only marginally reliable at best. It serves as a solid diagnostic tool for fast evaluation and identification, but it is not recommended for
more extensive assessment (191). The initial AP view is able to provide a solid view of the anterior pelvic structures and can be used to detect a majority of injuries. However, it is not useful in the evaluation of the acetabulum and other posterior elements. In these instances, additional views of the pelvic inlet, pelvic outlet, and judet views may be necessary to identify injuries (188).

The portable pelvic imaging process has specific criteria that are necessary to follow to ensure that the evaluation is accurate. These criteria include required anatomy for diagnosis, correct positioning of the body part, and adequate radiographic exposure technique (190). Therefore, when the technologist is brought to the emergency room to conduct pelvic X-rays using the portable pelvic X-ray machine, he or she will follow standard protocol for administering portable pelvic X-rays (192). Due to the trauma sustained by the patient and the potential for additional damage, the portable X-ray images will most likely be taken while the patient is in the “as in” position, meaning that the patient will not be moved into a different position to facilitate imaging (190).

In instances where the patient is immobilized using a spine board, the images will be obtained by placing the cassette under the board rather than between the patient and the board. This will prevent unnecessary movement of the patient and minimize agitation of the injury (77). When the patient is on a Stryker type bed, the cassette tray may be placed under the mattress in the special cassette tray, once again minimizing unnecessary movement. The cassette tray is positioned under the bed so that the patient does not have to be moved at all to place the cassette beneath the mattress (175).

A Stryker type bed is often used with patients who may have spine and/or pelvic damage as it helps to maintain the necessary precautions for them during the initial assessment and identification phase. The Stryker type bed allows for assessment procedures without requiring that the patient be moved to do so (193). When a Stryker type bed is in use, the proper positioning of the patient
and the cassette is necessary to ensure that the images are accurate. The accurate placement of the cassette requires an experienced technician who understands how to align the tube, part and cassette (132). The following are the instructions for proper tube-part-cassette alignment:

Alignment of the cassette to the top of the patient’s iliac crest is achieved by adjusting the longitudinal lock on the cassette slide tray. Besides including the required anatomy the technologist must make sure grid cut-off does not occur. So use the maximum source-image-distance allowed by the grid focus range and portable unit. Part-tube-cassette alignment is critical to getting a good radiograph. Object film distance is also an important factor when imaging through a Stryker type bed because it can be a cause of excessive part magnification. Patient size, body composition, the spine board material, and mattress through which the x-ray beam must pass are to be considered when setting the radiographic exposure technique. (194)

The diagnostic criteria for the AP Pelvis view are listed below (190):

- Include the anatomy from the top of both iliac crest superiorly through the ischial tuberosities, and the inclusion of both lesser trochanters of the femurs.
- The lateral margins of the film (14 X 17) should include the anterior portions of the iliac wings, which is the anterior part of the pelvis. Do not internally rotate the femurs during trauma imaging of the pelvis.
- The radiographic exposure technique should demonstrate good bone detail. Soft tissue shadows should include the urinary bladder, pelvic portion of the iliopsoas muscle, rectum, and bowel gas.

If the technician is unable to meet the specific criteria established for the portable pelvic radiograph, it will be necessary to repeat the process to incorporate the full
criteria. Typically, this will have to occur once the patient is stable enough to be transported to the radiology department for further diagnostic imaging (194).

The initial portable pelvic imaging is a necessary step in the assessment and diagnostic process. Using the AP view, the trauma team will be able to conduct an initial, immediate assessment of the pelvic region to determine the extent of injuries. The following are listed as the most serious pelvic injuries (187):

- pelvic ring fracture
- acetabular fracture
- rupture of the urinary bladder
- transection of the urethra

The AP pelvic image can identify the presence of abnormalities that may require additional radiograph imaging. If additional images are necessary, they typically involve inlet and outlet images and oblique (Judet) views of the pelvis (if acetabular fractures are seen) (193).

The following is a description of the pelvic inlet and outlet views and the type of determinations one can make from diagnostic imaging in these regions:

*The pelvic inlet is formed by two arching lines that begin posteriorly with the sacral promontory and extends anterolaterally as the arcuate lines and pectin on the superior pubic rami. The pelvic inlet is the opening into the true pelvis, which houses the urinary bladder and rectum in both genders, and the uterus in females. The inlet view is an important view of the pelvis when there is posterior displacement of the SI joint and/or rotation of the hemipelvis. The inlet view is taken with the patient supine and the x-ray tube angled 45 degrees caudal and perpendicular to the pelvic brim. The following are some of the determinations permitted by the inlet view:

- The degree of posterior displacement at the SI joint.
- The degree of internal or external rotation of the hemipelvis.
- The degree of pubic diastasis or overlap.*
• The presence of subtle sacral fractures or sacral impaction.

The primary purpose of the outlet view is to demonstrate the magnitude of vertical hemipelvis displacement. The sacral foramina are better depicted on the outlet view than with the AP view. Additionally, some sacral and pubic rami fractures are better visualized with the outlet view.

• Can corroborate vertical displacement of the hemipelvis.

• Demonstrates the sacral neural foramina better than the AP view alone.

• Some pubic fractures are also better demonstrated in this view.

• Outlet view is obtained with the patient in the supine position, with the x-ray tube angled 45 degrees cephalic and perpendicular to the sacrum. (194)

Extracorporeal Membrane Oxygenation (ECMO)

Extracorporeal Membrane Oxygenation (ECMO) is used in trauma patients to provide life support to the patient that will aid in recovery of the heart and lungs. Using a heart-lung bypass machine, ECMO provides long-term breathing and cardiovascular assistance to patients while they are recovering from trauma (195). Patients may use ECMO for a number of days or weeks while they are being treated for other injuries.

The machine used for ECMO similar to the one used during open-heart surgery. It pumps blood from the patient’s body into the machine, where oxygen is added and carbon dioxide is removed. This process mimics that of a healthy, stable lung (162).

There are two types of ECMO:

• Venovenous (V-V) ECMO is used when the heart is functioning well and only the lungs need to rest and heal.
- Venoarterial (V-A) ECMO is used when the heart as well as the lungs need to rest and heal. (196)

**LEARNING BREAK:**
What are the challenges of providing nursing care to the polytraumatized patient? What role do nurses and associates play in the assessment and treatment process?

### SECONDARY SURVEY

Once a polytrauma patient has been stabilized and has undergone the initial assessments and diagnostic tests to identify the specific injuries and treatment needs, the treatment team will begin the secondary survey. While the information gleaned from this survey is crucial, it is often delayed due to the immediate risk of the injuries and the need to treat the patient upon arrival (8). However, once the patient is stable, the information gathered during the secondary survey is of utmost importance.

*Secondary Survey*

The secondary survey is performed only after the primary survey has been finished and all immediate threats to life have been addressed. The secondary survey is a head-to-toe examination designed to identify any injuries that might have been missed (197).

*Specialized Tests*

Once the primary survey is complete and all life threatening injuries have been identified and treated, the treatment team will begin administering specialized diagnostic tests to identify any additional, potentially life threatening injuries. The patient must be stabilized prior to beginning these specialized tests (198). In addition to being stable, the patient must also have normalized hemodynamic and ventilation status.
The most common specialized diagnostic tests include the following (166):

- CT scanning
- Extremity radiography
- Endoscopy
- Formal ultrasonography

Once specialized diagnostic testing has been completed, the patient should be treated accordingly. However, regular monitoring is required to ensure that the patient remains stable and to identify any trends in both the physical examination findings and the laboratory results (8). The patient should be treated accordingly throughout the process. However, caution should be exercised, as the treatment team should not hinder the identification and evaluation process by minimizing the patient's ability to identify areas of concern (163).

**Focused Patient History**

Once the patient has completed the specialized diagnostic testing, the treatment team will complete a focused patient history. Initially, the history will focus on the trauma as well as any information that is pertinent to the treatment of the patient (199).

The following information is gathered during the focused patient history (197):

- Symptoms - Pain, shortness of breath, other symptoms
- Allergies to medications
- Medications taken
- Past medical/surgical history
- Last meal - Important to determine risk of aspiration
- Events leading up to trauma

**Head and Skull Examination**

During the secondary survey, the identification of head trauma is one of the highest priorities of the treatment team. An initial neurologic exam and a
noncontrast head CT scan are typically used to identify the following conditions (200):

- Intracranial bleeding, including subarachnoid hemorrhage
- Intracranial hemorrhage
- Subdural hematoma
- Epidural hematoma

Patients who present any of the following symptoms are suspected of having an intracranial injury (201):

- Focal neurologic signs
- Altered mental status
- Loss of consciousness
- Persistent nausea and vomiting
- Headache

Patients who show any of the above symptoms must be assessed and treated immediately, even when the symptoms may be explained easily by other intoxications or injuries (65). When an intracranial injury is suspected, the patient must undergo a head CT scan as soon as possible (assuming the patient is hemodynamically stable) to identify any injuries (201).

A standard head examination will include an assessment of the patient’s level of consciousness, eyes, and skull. The level of consciousness is evaluated using the Glasgow Coma Scale (76). The eyes are assessed for visual acuity, pupillary size, and extraocular movements (202). In patients with a suspected preretinal hemorrhage, a fundoscopy is used (201). The skull examination includes palpitations for lacerations, tenderness and fractures (203).

It is important to be aggressive when treating and managing head trauma, especially when hypoxia and hypotension are present, as they can cause
secondary brain injury (204). Therefore, a neurosurgeon is often consulted immediately to provide further assessment (8).

Maxillofacial Examination
Another component of the secondary survey is the maxillofacial examination. While facial injuries rarely pose a significant threat to the patient, they are still important components of the diagnostic process (2). Typically, the maxillofacial examination will include a survey of the mouth and nose with the goal of identifying any bleeding or hematomas. In addition, the maxilla and the mandible are checked for instability that may be associated with Le Fort fractures (205). In instances when the airway is impacted, intubation may be required as an additional protective mechanism (12). Without this early protection, the airway may become compromised at a later time due to tracheal swelling and/or excessive secretions (205).

Neck Examination
A neck examination is an important component of the secondary survey as there are three significant structures that make up the anterior neck region. These include the trachea, pharynx/esophagus, and great vessels. In addition, the neck holds the spine in the posterior region. When a patient experiences penetrating trauma to the neck, it is necessary to complete a thorough examination of the region, especially if the trauma involves the superficial fascia and the muscles of the neck (206). In these instances, it is recommended that an otolaryngologist or general trauma surgeon examine the patient (207).

Chest Examination
Thoracic injuries pose a significant risk during trauma situations. In fact, approximately 25% of trauma related deaths are a result of thoracic injuries (185). Therefore, early identification of chest trauma is crucial to the treatment and recovery process. While thoracic injuries pose a significant risk, the majority of them can be treated and managed by a general emergency physician (208).
In some instances, the injury may be severe enough to warrant a thoracotomy or other special surgical procedures, which will require a specialist (185).

The first part of the chest examination should include a general evaluation for an apparent bruising or deformity (197). An examination of the chest wall during respiration will also be conducted to monitor motion (208). In addition, the heart will be auscultated for any muffled sounds or murmurs that may be indicative of traumatic valvular damage (209). The lungs will be auscultated for breath sounds (208). Finally, the chest will be palpated for any subcutaneous emphysema or bony crepitus. The presence of these may indicate tracheobronchial disruption or rib fractures (209).

The following is a list of injuries that should be considered and identified during the chest examination (197):

- **Traumatic rupture of the aorta** -
  
  **Diagnosis:** Use chest radiography to screen for a widened mediastinum or other signs of rupture. Aortography is cumbersome and is used infrequently. The definitive diagnosis is made with CT angiography of the chest, or transesophageal echocardiography.

  **Treatment:** Use an interpositional graft or repair the rupture.

- **Tracheobronchial disruption** -
  
  **Diagnosis:** Consider this diagnosis if a collapsed lung does not expand after chest tube insertion, a massive air leak persists, or progressive subcutaneous emphysema is noted.

  **Treatment:** Perform bronchoscopy and surgical repair.

- **Diaphragmatic disruption** -
  
  **Diagnosis:** Stomach (gastric bubble) and/or bowel can be seen in the thorax on chest radiographs, CT scans, or laparotomy findings.
Treatment: Insert a nasogastric tube to decompress the stomach; then, perform surgery.

- Blunt cardiac injury -
  **Significance**: This may cause contusion, chamber rupture, or valvular disruption.
  **Diagnosis**: ECG and cardiac echo aid in diagnosis.
  **Treatment**: Consult with a cardiothoracic specialist for rupture, valve disruption, or contusion; monitor the patient for 6-24 hours for arrhythmias.

- Pulmonary contusion -
  **Diagnosis**: Pulmonary opacities can be seen on chest radiographs.
  **Treatment**: Avoid fluid overload if the patient is fluid-resuscitated. Administer oxygen and analgesia, and consider intubation.

- "Blast lung" –
  Blast lung is seen with high-energy explosive injuries, such as terrorist bombings. Signs may be immediate or may be delayed up to 48 hours.
  **Diagnosis**: Pulse oximetry and chest X-ray, and ABG analysis.
  **Treatment**: Monitor for tension pneumothorax and/or hemothorax. Provide mechanical ventilation. Aggressive fluid administration may be needed.

- Simple pneumothorax -
  **Significance**: This can develop into tension pneumothorax, especially if intubation and positive pressure ventilation are used.
  **Treatment**: Chest tube placement is indicated.

- Hemothorax -
  **Significance**: This may become a massive hemothorax, may clot, and may cause lung entrapment or become an empyema.
  **Treatment**: Chest tube placement is indicated.
• Mediastinal traversing wounds -

  **Significance**: This may cause damage to the heart, great vessels, tracheobronchial tree, or esophagus.

  **Treatment**: Patients with symptomatic, hemodynamically unstable, and mediastinal traversing wounds are immediately taken to the operating room. Patients with stable mediastinal traversing wounds undergo an extensive workup with CT angiography, esophagraphy, and bronchoscopy/endoscopy in consultation with a surgeon.

**Abdominal Examination**

Abdominal trauma is categorized by type of injury, either blunt or penetrating. The initial abdominal examination will vary depending on the category of injury. If the patient has a potential blunt abdominal injury, a thorough examination is necessary as many blunt injuries can be subtle and may not be immediately apparent (210). In these patients, the abdomen should be examined first for any surgical scars, contusions, or lacerations (211). The abdomen should be palpitated for tenderness or any abnormalities (210). Finally, the treating provider should listen for bowel sounds (198). Once the initial exam has been completed, the patient may require FAST (focused assessment sonography in trauma) or DPL (diagnostic peritoneal lavage) to identify any potential intra-abdominal bleeding (211).

The following is a description of FAST and DPL:

*FAST is a quick, sensitive way to detect fluid in the abdominal cavity.*

*FAST can detect as little as 300-500 mL of free fluid. FAST can be accurately performed by properly trained physicians or surgeons. The limitations of FAST are operator dependence; an inability to detect retroperitoneal blood (e.g., from pelvic fractures); and an inability to differentiate blood from urine, ascites, or other abdominal fluid.*
DPL is a sensitive technique for detecting intra-abdominal blood. The advantages over FAST include increased sensitivity and the ability to analyze the type of intraperitoneal fluid (e.g., blood, ascites in cirrhotic patients, bowel contents). The disadvantage is that DPL takes longer than FAST and is invasive. With the advent of fast spiral CT scanners, DPL is infrequently resorted to.

In the presence of hypotension, a positive FAST or DPL result is an indication for immediate laparotomy (197).

In instances where the patient has a potential penetrating abdominal injury, immediate identification is necessary. These patients are typically transferred immediately to the operating room for a laparotomy to identify any potentially life-threatening injuries (211). If the following are present, a laparotomy is administered (211):

- Evisceration
- Penetrating injuries caused by firearms or objects
- Any injury accompanied by shock, free air under the diaphragm on chest radiographs
- Peritoneal signs

Spinal Cord/Vertebral Column

During the secondary examination, patients will be assessed for any spinal cord or vertebral column injuries. The provider will first assess point tenderness by palpating the spinous processes (178). If any point tenderness, bony step-offs, or abnormalities are apparent, the patient will undergo a spinal radiography to determine the extent of the damage (177). If a patient has a spinal fracture, the spine will be immobilized and the patient will require a consultation with a spinal surgical specialist (212). If the patient presents with hypotension or a slow pulse, additional assessments will be conducted to determine if there is a high spinal cord injury or neurogenic shock (213).
Once the patient has completed the initial spinal and vertebral assessment, he or she will undergo a complete neurologic examination, which includes motor and sensory examinations and reflex assessments (142).

As part of the secondary evaluation, the patient must receive clearance for a cervical spine fracture (178). If a patient has a potential cervical spine fracture, he or she must be immobilized with a hard collar until an examination can be conducted to make a final determination (212). The determination of a potential cervical spine fracture is based on the patient’s history, initial physical examination, or mechanism of injury (178).

A patient will receive a cervical spinal fracture clearance if he or she meets the following criteria:

- No focal neurologic deficits
- No distracting injuries, e.g., gunshot wound, pelvic fracture, long bone fracture
- No intoxications (e.g., alcohol, opiates)
- Full orientation and awareness
- No midline neck tenderness (Instruct the patient to slowly rotate the head from side to side. If this is performed without pain or tingling sensations or numbness of the extremities, that patient almost certainly does not have a cervical spine fracture (99.8% negative predictive value). Other patients must have a minimum of 3 cervical spine radiographs (i.e., lateral, anteroposterior, and open-mouth odontoid views) and potentially other imaging studies to rule out cervical spine involvement.) (197)

**Genitourinary Examination**

A genitourinary examination is regularly performed as part of the secondary examination. The examination includes a rectal examination, perineal examination, and genital/vaginal examination (197). During the rectal examination, the patient’s rectal tone will be assessed as poor rectal tone is in
indicator of a spinal cord injury (214). The stool is examined and assessed for fresh blood, which is an indication of an open pelvic fracture or a laceration of the rectum (194). The patient is also assessed for urethra injuries, such as a high riding prostate, blood at the meatus, or a scrotal or perineal hematoma (197). If it is determined that the urethra is uninjured, a catheter will be inserted (12).

**ACUTE CARE**

Acute care is the stage of care that immediately follows patient stabilization. During this stage of care, any immediate injuries are treated and the patient receives additional evaluation and assessment (215). In most instances, the patient will be admitted to the Intensive Care Unit or a Trauma Center for acute treatment (198). As part of the process, the patient will undergo additional radiologic testing and continuous monitoring. The patient will receive treatment for all injuries with the goal of initial recovery and damage mitigation.

The acute care stage is intended to repair injuries and further stabilize the patient (12). While the patient will not likely experience a full recovery during the acute care stage, he or she will see some initial improvement beyond initial emergency treatment (216). Once a patient has completed the acute stage of care, and is more stable, he or she will transition to a long-term rehabilitation and recovery program (12). The services provided during the acute stage of care will depend on the specific needs of the patient and may include: surgery, fracture repair, burn care, internal injury treatment, as well as any other needed treatment.

**LONG TERM TREATMENT AND REHABILITATION**

Once a patient has received initial treatment and care and is in the recovery stage, long-term treatment and rehabilitation becomes the priority. In some instances, the patient will not require any long-term care beyond that received
during an extended hospital stay (13). However, many patients, especially military polytrauma patients, will require long term treatment and rehabilitation for the injuries sustained during the trauma. This type of care is most common in instances of traumatic brain injury and for patients who need to regain specific functions, such as mobility (69). Long term care and rehabilitation is also recommended for patients who experience severe emotional trauma and distress (217).

When a civilian requires long-term treatment and rehabilitation, it is typically conducted through private specialization centers and outpatient care facilities. The individual will work with his or her care provider to determine the specific treatment and rehabilitation needs, as well as identify and arrange for the appropriate treatment services (13). In military polytrauma cases, the patient is typically referred to a military polytrauma specialization center for long-term care and rehabilitation. In these instances, the Department of Veterans Affairs provides and/or arranges for all of the necessary services that the patient needs during recovery and rehabilitation (218).

**Military Polytrauma Specialization Centers**

There are five military polytrauma specialization centers throughout the country that provide services for military personnel who have been involved in polytrauma situations. The polytrauma specialization centers are part of an extensive network of polytrauma resources specifically for military personnel. This network is comprised of polytrauma rehabilitation centers, polytrauma transitional rehabilitation programs, and polytrauma network sites. In addition to these sites, there are 86 Polytrauma Support Clinic Teams located through out the VA Healthcare System (218).

The Department of Veteran’s Affairs provides the following explanation of the services offered at the various polytrauma centers:

*Acute Long-Term Care*
If a Veteran or Service member needs acute long-term care and rehabilitation, he or she will likely enter one of the 5 Polytrauma Rehabilitation Centers (PRC). Following initial assessments, the members of an interdisciplinary medical team will have an admission conference, typically within the first week or second week of admission, to discuss their findings and to design a rehabilitation treatment plan, including an estimated length of stay. The patient and family/caregiver will be informed about the team’s findings and recommendations following the conference and be encouraged to provide input about goals and expectations for rehabilitation. The team also meets in weekly rounds to evaluate the patient’s progress and to adjust or redefine the treatment goals accordingly.

Mild to Moderate Cases
The next step in a patient's recovery is often a Polytrauma Network Site (PNS). The PNS offers continued medical care and rehabilitation services for those who are transitioning closer to home following discharge from a PRC. PNS programs will also be the entry point for those who have experienced a mild or moderate Traumatic Brain Injury (TBI). Depending on need, services may be provided on an inpatient or outpatient basis.

Polytrauma Support Clinic Team (PSCT) programs, located in 87 VA medical centers across the country, may be the next step for a patient. PSCT programs offer continued medical and rehabilitation care closer to a patient’s home community (219).

The following is a list of the polytrauma rehabilitation centers:

- Richmond, VA
- Tampa, FL
- Minneapolis, MN
- Palo Alto, CA
Polytrauma Rehabilitation Centers

Polytrauma Rehabilitation Centers (PRC) provide the most comprehensive acute rehabilitative services for military polytrauma patients. These centers provide services on an inpatient basis to service members who require extensive treatment (218). Polytrauma rehabilitation centers are staffed with an interdisciplinary team of specialists who can address the varying treatment and rehabilitation needs of the patients (219).

The PRC interdisciplinary teams include the following subspecialists (220):

- Physiatrist (rehabilitation doctor)
- Social Work Case Manager
- Nurse Case Manager
- Physical Therapist
- Occupational Therapist
- Recreation Therapist
- Rehabilitation Nursing
- Speech and Language Pathologist
- Rehabilitation Psychologist
- Neuropsychologist
- Vocational Rehabilitation Counselor
- Active Duty Military Liaison
- Blind Rehabilitation Specialist
- Certified Prosthetist/Orthotist
- Chaplain
- Other consultative services as needed (e.g., Neuro-ophthalmology, Orthopedics, Nutrition, Neurology, Psychiatry, Audiology, Surgery)

Polytrauma Transitional Rehabilitation Programs

Polytrauma Transitional Rehabilitation Programs (PTRP) provide: “time limited, goal oriented, residential rehabilitation programs that partner with Veteran and Service member participants to improve their physical, cognitive, communicative,
behavioral, psychological, and social functioning after significant injury or illness” (218).

According to the Department of Veteran’s Affairs, “the overarching goal of the PTRPs is to help participants return to the most appropriate, least restrictive community setting, by targeting skills necessary for return to home, school, work, or military service, as feasible (221).”

The PTRPs provide the following services (221):

- Offer interactive therapy programs designed to address the individual needs and goals of each participant.
- Challenge participants through a wide range of individual and group therapeutic activities and living skills practices.
- Focus heavily on community reintegration activities.
- Employ teams of licensed and credentialed rehabilitation professionals who provide patient-centered, integrated care.

There are five Polytrauma Transitional Rehabilitation Programs in operation in the United States. They are located in the following US regions (220):

- Minneapolis, MN
  The Minneapolis VA Medical Center serves as the tertiary referral center for the VA Midwest Health Care Network and has 199 acute care diagnostic and treatment beds and 80 extended care beds

- Palo Alto, CA
  The VA Palo Alto Health Care System (VAPAHCS) is one of the VA’s largest health care referral centers with three hospital-based divisions and a network of six outpatient clinics. More than 85,000 veterans are enrolled in care at the VAPAHCS.

- Richmond, VA
McGuire VA Medical Center is a 427-bed facility, centrally located in Richmond, Virginia, offering primary, secondary, and tertiary health care in medicine, surgery, neurology, rehabilitation medicine, skilled nursing home care, and palliative care.

- Tampa, FL
  The James A. Haley VA Medical Center is a 327-bed tertiary care teaching hospital dedicated to providing the highest quality of inpatient, outpatient, and rehabilitation care and services to Veterans and eligible Service members in Central Florida.

- San Antonio PRC
  The South Texas Veterans Health Care System (STVHCS) is an award-winning organization with inpatient facilities in San Antonio and Kerville, Texas. San Antonio is known as "Military City USA" and STVHCS staff has a continuing close partnership with Department of Defense medical facilities. We offer world-class health care to Veterans and Service Members

**Polytrauma Network Sites**

After acute rehabilitative care is provided at the Polytrauma Rehabilitation Center, many service members will transition to a Polytrauma Network for additional care that is less intense and more focused. The Polytrauma Network Sites are located in each Veterans Integrated Service Network (VISN). Currently, there are 23 specialized rehabilitation programs located throughout the United States. The PNSs are described to:

“*offer continued medical care and rehabilitation services for Veterans and Service members who are transitioning closer to home following discharge from a PRC. PNS programs are also the entry point for rehabilitation services for those who have experienced a mild-moderate TBI or*
polytraumatic injury. Depending on need, these services may be provided on an inpatient or outpatient basis (222)."

The PNS Interdisciplinary teams include the following health team members (222):

- Physiatrist (rehabilitation doctor)
- Social Work Case Manager
- Nurse Case Manager
- Physical Therapist
- Occupational Therapist
- Recreation Therapist
- Rehabilitation Nursing
- Speech and Language Pathologist
- Rehabilitation Psychologist
- Neuropsychologist
- Military liaison
- Blind Rehabilitation Specialist
- Certified Prosthetist/Orthotist
- Other consultative services as needed (e.g., Ophthalmology/Optometry, Orthopedics, Neurology, Psychiatry, Surgery and Vocational Rehabilitation)

Each polytrauma rehabilitation center houses a Polytrauma Network Site. In addition, there are 18 separate network sites.

- Boston, MA
- San Juan, PR
- Houston, TX
- Syracuse, NY
- Lexington, KY
- Dallas, TX
Private Specialization Centers
Civilian patients, who do not have access to the extensive network of special care centers offered through the Department of Veteran’s Affairs, will often be referred to private specialization centers after the initial treatment phase. Typically, these centers are injury specific. For example, an individual who suffers severe burns will be transferred to a burn trauma center for long-term care and treatment. There are a number of specialization centers in operation, and referral to one of these centers will depend on the extent and severity of the injury (13).

Outpatient Care and Support
Once a polytrauma patient has completed the initial stage of treatment, long term care and support becomes the focus. Due to the severity and long-term impact of many of the injuries sustained during trauma situations, patients will often require additional services, which are available through outpatient centers and support programs (223). The specific type of care and support is dependent upon the type of injury and the specific needs of the patient. Typically, outpatient care involves one or more of the following services:

- Bronx, NY
- Cleveland, OH
- Tucson, AZ
- Philadelphia, PA
- Indianapolis, IN
- Denver, CO
- Washington, DC
- Hines, IL
- Seattle, WA
- Augusta, GA
- St. Louis, MO
- West Los Angeles, CA
• Physical therapy
• Occupational therapy
• Speech and language therapy
• Psychiatric care
• Psychological services
• Social support and life skill development
• Physiatry
• Long term medical treatment (13)

As with other types of private care, outpatient care will be determined by the treating physician and will address the specific needs of the patient.

MENTAL HEALTH TREATMENT

Many polytrauma patients will experience emotional distress or mental health issues as a result of the trauma. In some patients, the effects may be severe and require long-term mental health treatment (217). However, other patients may only require short-term emotional assistance (224). The type and extent of services needed will depend on a number of factors including the previous mental state of the patient, the type and level of trauma experienced, the severity and long-term impact of the injuries, and the changes in the patient’s lifestyle or ability to function as a result of the trauma (217). Post Traumatic Stress Disorder (PTSD) is a common occurrence among individuals who have experienced polytrauma, especially military personnel (31). In addition, many patients experience emotional distress in response to the changes in ability and functioning that have occurred as a result of injuries (225).

Patients can receive mental health treatment from a variety of providers, including the following (223):
• Social Workers
• Therapists
• Case Managers
• Psychologists
• Psychiatrists
• Family Care Providers
• Counselors

The patient will be referred to one or more of the mental health professionals depending on his or her specific needs. In some instances, the mental health treatment will be short term as the patient is adjusting to the changes brought on by the polytrauma. In other instances, the treatment will be long term to address severe mental trauma or psychological distress (217).

**SUMMARY**

Polytrauma is the leading cause of death to patients due to the extent and severity of the injuries sustained. It occurs as the result of both military and civilian accidents. In combat situations, polytrauma is caused primarily by blast related trauma, while civilian trauma can be caused by a number of incidents including motor vehicle accidents, bicycle accidents, firearms, industrial accidents, and any other accidents that have the potential to cause severe injuries. Polytrauma is complex and requires a diverse range of services to best meet the needs of the individual patient. Polytrauma care providers must be able to provide initial care that is focused on patient stabilization, while also working to address any secondary issues that are caused by the trauma.

Due to the diverse nature of the injuries sustained during polytrauma, it is important to understand how to identify and treat polytrauma patients. Patients will require immediate treatment to provide stabilization and prevent any further damage, followed by acute care to support the patient as he or she recovers.
Once a patient has recovered, long term care and rehabilitation may be needed to assist the patient with any long-term affects of the polytrauma. Therefore, the provider must be aware of and understand the different stages of polytrauma care to best provide the patient with the appropriate services and referrals. With appropriate care, a patient may be able to recover from the severe injuries sustained during polytrauma and function throughout the remainder of his or her life.
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