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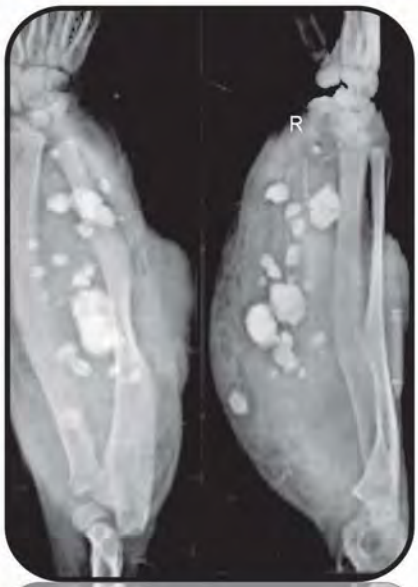
2 nd Edition



Fundamentals of ORTHOPEDICS







Mohindra • Jain

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3 CHAPTER

Management of Polytrauma Patients and Open Fractures

MANAGEMENT OF A POLYTRAUMA PATIENT

INTRODUCTION

Traumatology (trauma; greek; injury or wound) refers to study of injuries or wounds caused by accident or violence to a person. With cases on rise as if an epidemic, this domain now forms the backbone of Orthopedics. Over past century, world has witnessed many mass traumatic events like terrorist bombings, war disasters, rail accidents, fires, etc. and not uncommon for a surgeon is to encounter polytrauma patients in mass number.

Polytrauma patients are those patients who have sustained two or more severe injuries which endanger life [injury severity score (ISS) >18, *see* later]. The leading cause of polytrauma and death are road traffic accidents and mostly involved are the young and active population of society. Care of these polytrauma patients begins right from the scene of the accident. Highly coordinated team efforts are required to manage the victims effectively. Often these patients are a part of mass casualty and hence the immediate step that comes into operation is triage.

TRIAGE

In case of mass casualties the injured persons often outnumber the helping medical experts. The immediate step in such situation is to sort the patients based on their need for treatment and the resources available, this process is called *triage*. Simply this is a system deciding which patient should be treated first, depending on how severe they are injured. Patients are sorted into four color-coded groups of priority based on their need for evacuation and immediate treatment as outlined below:

1. *Priority 1 (Red)—(Immediate care needed):* These patients cannot survive without immediate treatment, but have a chance of survival with immediate intervention.
2. *Priority 2 (Yellow)—(Urgent care needed):* These patients are stable for the moment but require observation in a hospital. These patients have injuries that are less severe than red categories, but may be life or limb threatening if treatment is delayed beyond several hours. These patients may require a retriage.
3. *Priority 3 (Green)—(Delayed care needed):* These patients have only minor injuries and are tagged as walking wounded. These are segregated from more seriously injured patients of the above two categories and treated after the red and yellow category patients have been treated.
4. *Priority 4 (Black)—(Dead):* These are patients without obvious vital signs.

Priority 1 patients are those who are likely to deteriorate without medical help (requiring immediate intervention to save lives) are attended first while injured, but walking in patients with stable vitals, classified into delayed (Priority 3) category, are attended later as the situation permits.

GUIDELINES FOR CARE OF SERIOUSLY INJURED

Once the priority order is decided, the doctor in emergency starts attending the priority 1 patient. The first step is to ensure that the patient in question does not have a cardiac arrest. The recommendation [by American Heart Association (AHA)] is to check the carotid pulse for atleast 10 seconds while simultaneously assessing the breathing pattern of the patient. Three situations may arise **(Flow chart 3.1)**:

1. *Pulse detectable and patient breathing normally:* In this situation, the polytrauma patient is subjected to the Advanced Trauma Life Support protocol (ATLS, read later) described by the American College of Surgeons to prevent an impending cardiac arrest and hence collapse.
2. *Pulse detectable but breathing not normal:* The situation is characteristic of patients having respiratory depression secondary to causes like opioid poisoning. They should be managed according to suspected cause.
3. *Pulse absent and no normal breathing (e.g. gasping respiration):* These are the patients in cardiac arrest that need immediate cardiopulmonary resuscitation (CPR) and are subjected to the AHA's Basic Life Support (BLS) protocol (if resuscitation is performed without use of special equipment, drugs or invasive skills, as in collapsed patients lying roadside) or Advanced Life Support (ALS) protocol (if there is availability of equipment like cardiac monitors, endotracheal tubes, drugs, etc. as in an ambulance or hospital setting).

BASIC LIFE SUPPORT

This is a protocol for CPR that includes a series of steps that are instituted on an emergency basis in any collapsed patient suspected to have a cardiac arrest. The protocol is designed to be performed not just by a doctor, but a medical technician, a paramedic or even a qualified bystander who identifies such a patient. Since the care of the patient has to start from the accident scene, the protocol steps are designed barring the use of any special equipment, drugs or invasive skills (except a defibrillator that is available at most locations and is simple to use as automated equipment are largely installed in most locations).

Before the protocol is formally instituted, the performer is advised to brush through three quick steps to ensure personal as well as patient's safety. These are designated by mnemonic "DRS" viz. "Danger" (remove the patient from the site of danger like from middle of the road to a safe place), "Response" (command patient to assess his response to get a quick idea

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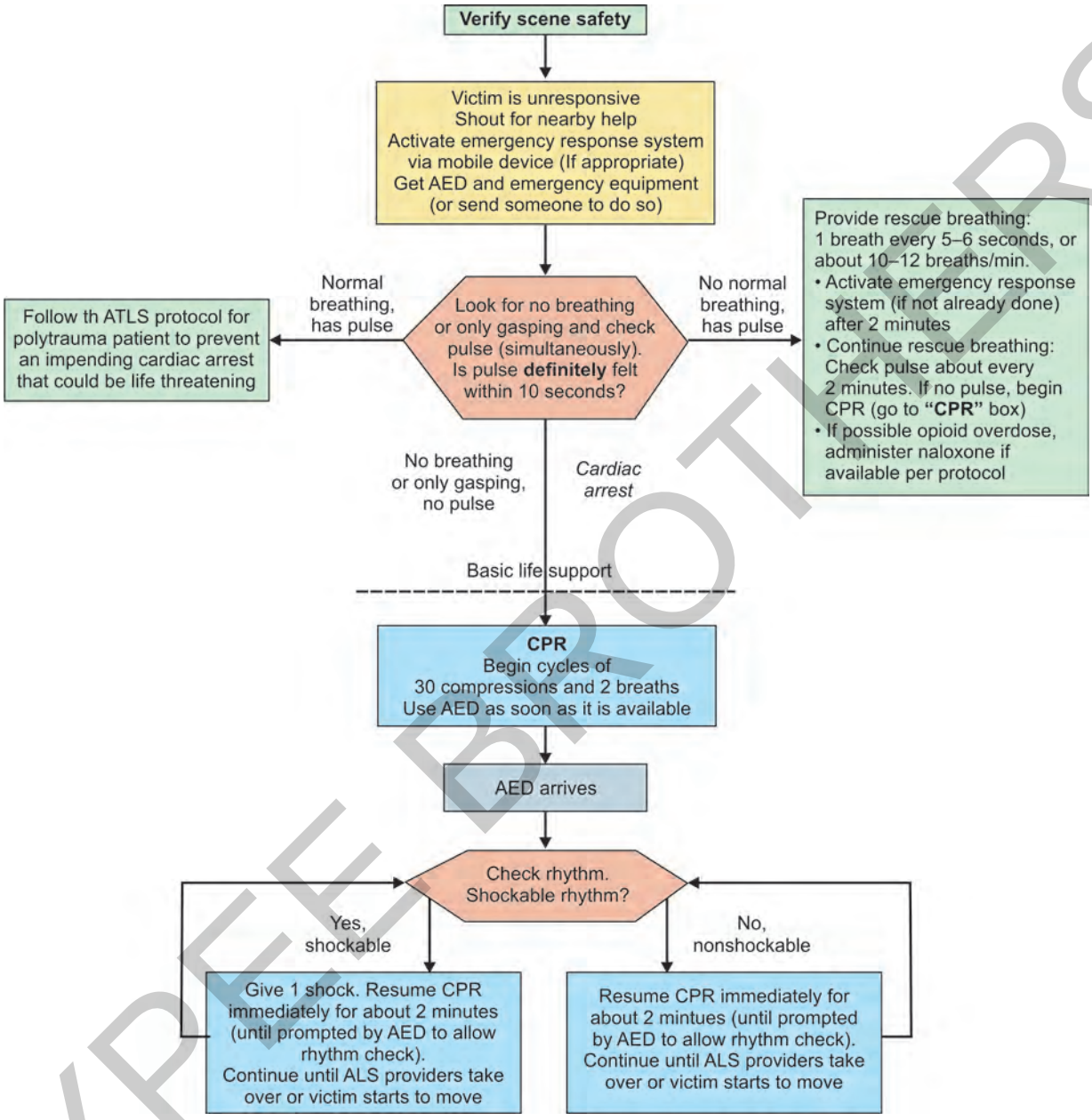
Flow chart 3.1: Emergency guidelines for the care of a seriously injured polytrauma patient (modified from American Heart Association's 2015 guidelines)



Abbreviations: ALTS, advanced trauma life support; AED, automated external defibrillator; CPR, cardiopulmonary resuscitation.

of the seriousness of the injury) and "Send for help" (alert the nearby persons of the situation and ask send them to seek immediate help or call an ambulance). Immediately thereafter the steps to be endorsed are best remembered by the mnemonic "CABD" viz. starting immediate "Chest compressions", managing "Airway", providing rescue "Breathing" and ensuring early "Defibrillation". The important details of each step are outlined here.

Chest Compressions

Chest compressions, take precedence even over airway assessment in patients with cardiac arrest. It is postulated that when a person enters into a cardiac arrest, the blood still has some oxygen that can be harnessed by the tissues in the body (as metabolic acidosis shifts the oxygen-hemoglobin dissociation curve). Immediate chest compressions ensure that the blood gets delivered to the dying tissues, buying them some additional time for survival. Compressions are given by placing both hands one on top of another, with "heel part" centered over the chest around two fingers above xiphoid (i.e. the lower tip of the sternum), while body weight is being used to administer compressions **(Figs 3.1A and B)**. 100–120 compressions are given per minute for all age groups and chest is allowed to recoil fully in between. For adults, children and infants, chest is pushed up to 5, 4 and 3 cm, respectively.

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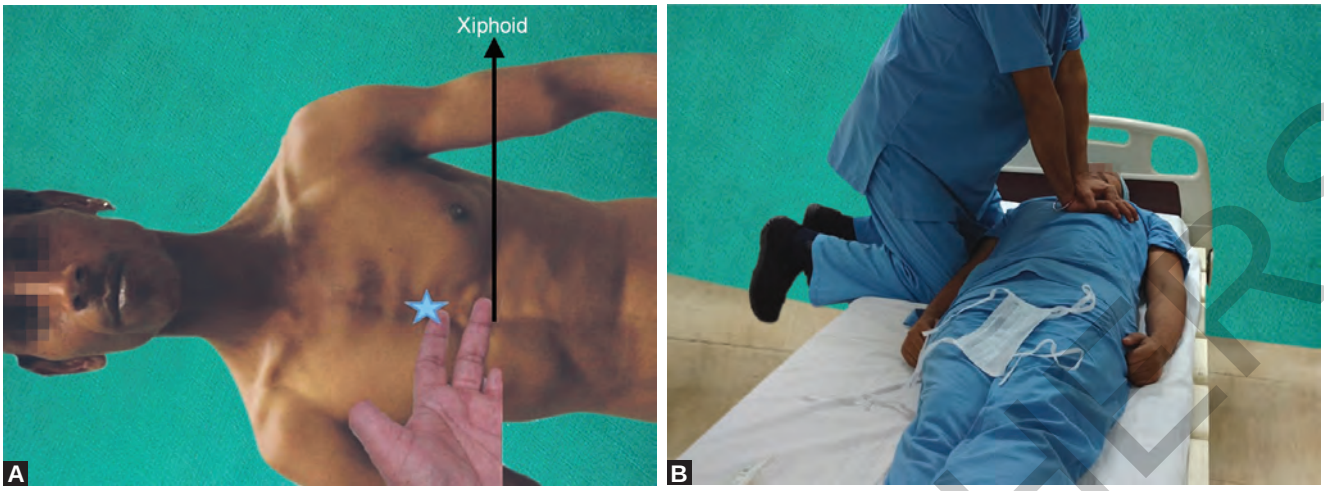


Figs 3.1A and B: (A) Site of chest compression (marked with a star) is two finger breadths above the xiphoid in the middle of the chest; (B) Doctor in action during a cardiopulmonary resuscitation (CPR). Note the hands one on top of another, elbows straight and the doctor up on bed to utilize his body weight to administer compressions via "heel" of his palm

Airway Management

Next step is to assess airway patency. Chin lift or jaw thrust (more effective) is the recommended maneuvers **(Figs 3.2A and B)** to establish the patency of a nonpatent airway. Blind finger sweeps should rather be avoided, as they may push foreign objects deeper into the airway. Once patent, the rescuer can try possible insertion of oral (oropharyngeal airway) or nasal (nasopharyngeal airway) adjuncts of proper size **(Figs 3.3A to C)** to maintain airway patency.

Breathing

Once the patency of the airway is secured, rescue breathing is to be provided. After every 30 chest compressions, give two rescue breaths in both adult and child victims, verifying that the chest rises and falls. Attempt the two artificial ventilations either using the mouth-to-mouth technique, or preferably a bag-valve-mask (BVM) apparatus **(Fig. 3.4)**, if available. The mouth-to-mouth technique is not recommended, unless a face shield is present. Continue for five cycles (or 2 minutes) of "CAB" before reassessing pulse.

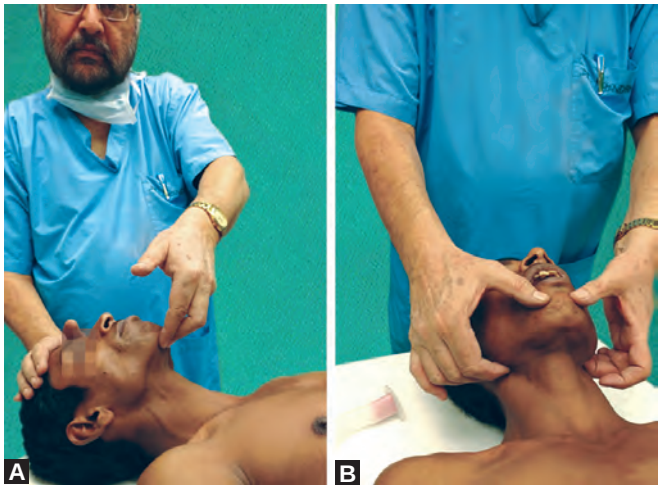
Defibrillation

While the rescuer is performing the CPR as described earlier, the helper is asked to arrange an automated external defibrillator (AED). The AED is to be used as soon as it is available **(Fig. 3.5)**. The device is attached to the patient's chest. It assesses the cardiac rhythm and guides the performer whether the rhythm is shockable or not. Give the shock if the AED prompts, else continue with CPR for another 2 minutes, after which the rhythm is to be rechecked by the AED. The BLS protocol continues until—(1) the patient regains a pulse, (2) the rescuer is relieved by another rescuer of higher training (i.e. an ALS team arrives, *see* later), (3) the rescuer is too physically tired to continue CPR, or (4) the patient is pronounced dead by a medical doctor.

ADVANCED LIFE SUPPORT AND ADVANCED CARDIOVASCULAR LIFE SUPPORT

Advanced Life Support is a treatment consensus for CPR in patients with cardiac arrest and related medical problems (e.g. stroke), as agreed in Europe by the European Resuscitation Council, most recently in 2010. The Americans use a parallel protocol called Advanced Cardiovascular Life Support (ACLS), endorsed from the AHA, latest updated in 2015. These protocols are a continuum of the BLS protocol as the ambulance team arrives at the scene or patient reaches the hospital where there are certified practitioners (trained emergency medicine technicians or medics), having training and skills in the use of special equipment and invasive techniques (e.g. endotracheal intubation) and drugs (e.g. adrenaline, oxygen). The basic steps are the same as outlined earlier, however, the appropriate equipment is taken to use wherever needed, e.g. the laryngeal masks **(Fig. 3.6A)** or endotracheal tubes **(Fig. 3.6B)** to secure and maintain the airway, and drugs for managing cardiac arrest **(Table 3.1)**.

The most important point to highlight in the ALS system is the use of cardiac monitors to analyze the patient's heart rhythm. In contrast to an AED in BLS, where the machine decides when



Figs 3.2A and B: (A) Demonstrating chin lift technique; (B) Jaw thrust technique for achieving airway patency. The latter is preferred

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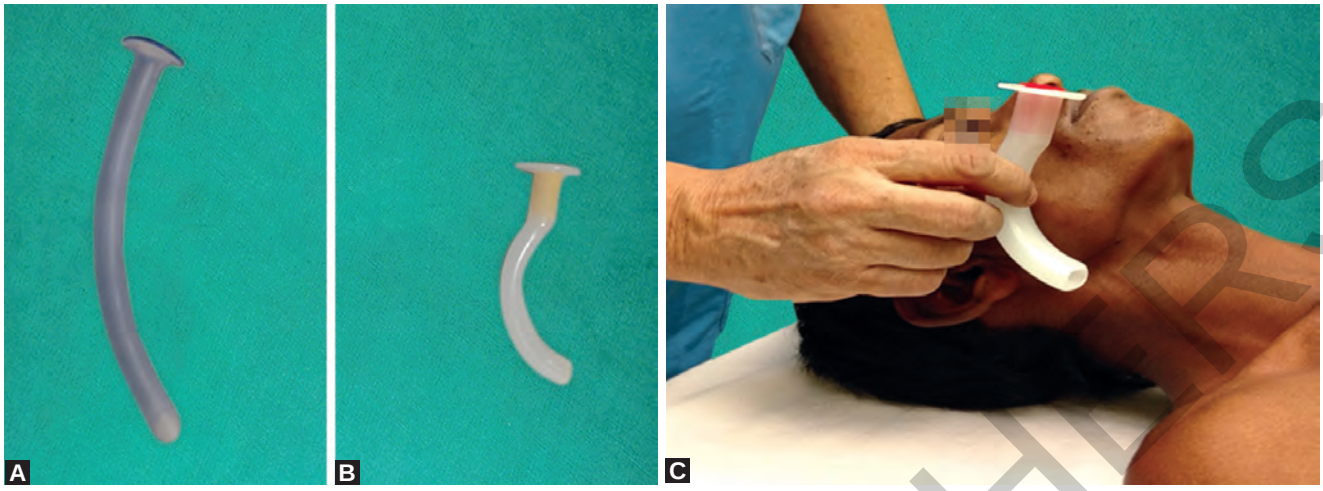


Figs 3.3A to C: (A) Nasopharyngeal airway; (B and C) Oropharyngeal airway, with the latter being sized from the incisors to the angle of the jaw

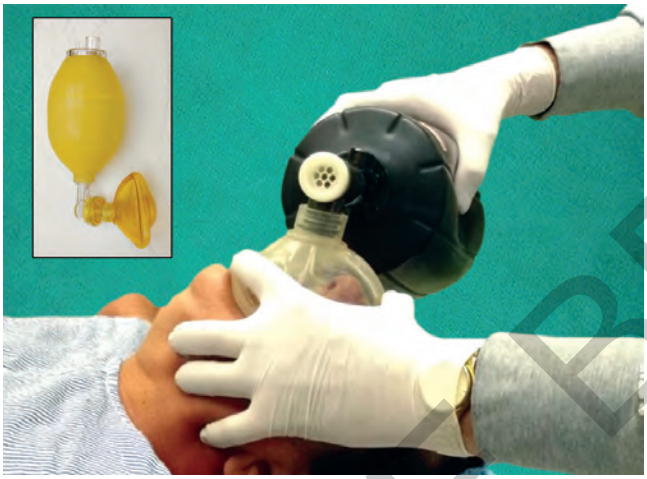
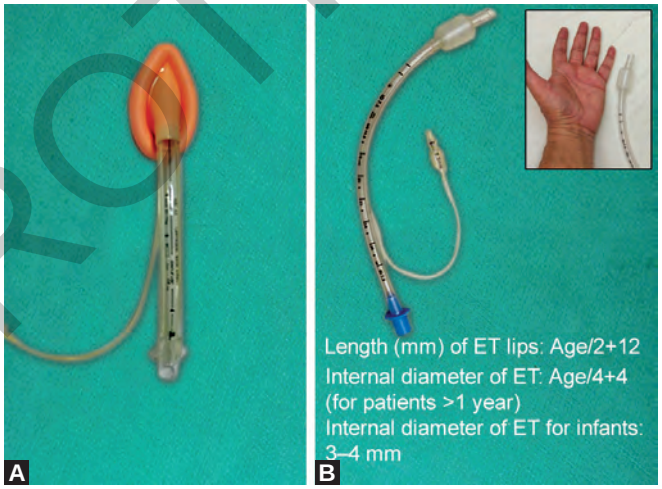


Fig. 3.4: Bag valve mask (inset) ventilation



Fig. 3.5: Automated external defibrillator (note the command on the screen directing the user for appropriate steps)



Figs 3.6A and B: (A) Laryngeal mask airway; (B) Endotracheal tube. The internal diameter of the tube generally chosen is matchable to the diameter of patient's little finger. However, correct ways to determine diameter and size are as shown in the **Figure 3.6B**

and how to shock a patient, the ACLS team leader makes those decisions based on rhythms on the monitor and patient's vital signs. Further steps in ACLS involve insertion of intravenous (IV) lines and placement of various airway devices and use of emergency drugs, such as epinephrine and amiodarone. An essential step in the ALS system is to quickly search for possible reversible causes of cardiac arrest (i.e. the Hs and Ts, **Table 3.2)**. Based on their diagnosis, more specific treatments are administered. These treatments may be medical such as IV injection of an antidote for drug overdose, or surgical such as insertion of a chest tube (or performing needle thoracocentesis) for those with tension pneumothorax. The legitimate factor in the decision to terminate resuscitation is an end-tidal CO_2 production ($EtCO_2$) of less than 10 mm Hg, measured on waveform capnography, after at least 20 minutes of resuscitation.

ADVANCED TRAUMA LIFE SUPPORT

Advanced trauma life support is a periodically updated, evidence-based training course (by the American College of Surgeons) for physicians and surgeons who are involved in the care of trauma

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Table 3.1: Drugs used in Advanced Life Support (ALS) protocol for cardiopulmonary resuscitation (CPR)

Rhythm	*Drugs**
Shockable	Adrenaline 1 mg after second shock and then every second cycle Amiodarone 300 mg after third shock
Nonshockable	Adrenaline 1 mg immediately and then every second cycle

**Caution:* Routine atropine use is no longer recommended unless there is a high risk for bradycardia.

Table 3.2: The Hs and Ts—reversible causes of cardiac arrest

The "Hs"	*The "Ts"*
• Hypoxia • Hypovolemia • Hypokalemia/Hyperkalemia • Hypothermia/Hyperthermia • Hydrogen ions (acidosis) • Hypoglycemia	• Tension pneumothorax • Tamponade cardiac • Toxins (medicinal poisonings) • Thromboembolism

patients. Concept behind ATLS is that save the life (i.e. prevent an impending cardiac arrest) by addressing the most dangerous threat to life first. "Correct sequence" for assessment and management of a polytraumatized patient (not in cardiac arrest or revived from arrest) is triage; primary survey; adjuncts to primary survey; patient transfer if needed; secondary survey; adjuncts to secondary survey; re-evaluation and definitive care.

Primary Survey

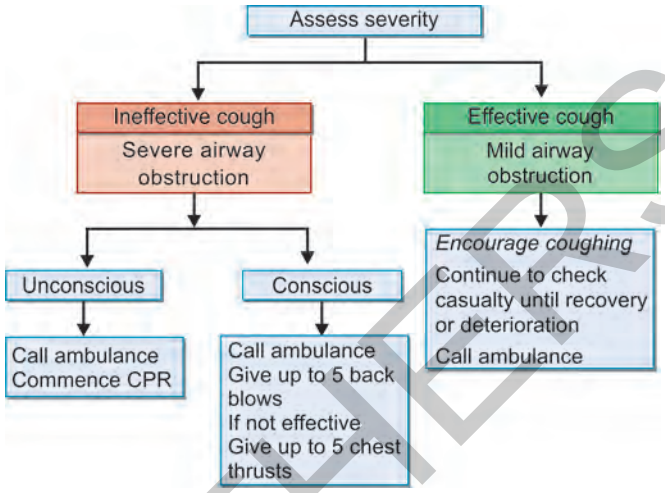
This part involves identifying and managing life-threatening injuries. A catastrophic exsanguinating external hemorrhage, if seen, should be immediately managed with a tamponade. Patients are rapidly assessed on the basis of "ABCDE" resuscitation protocol:

- **A**irway control with stabilization of the cervical spine.
- **B**reathing assessment—management of respiratory distress.
- **C**irculation—assessment of shock and management.
- **D**isability or neurological status—management of head injury.
- **E**xposure or undressing of the patient.

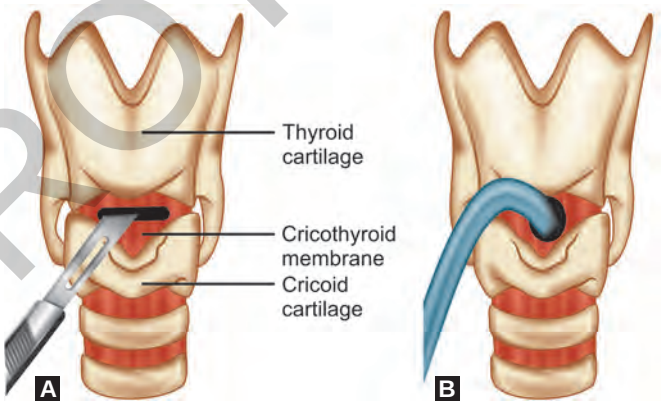
Airway Management with Cervical Spine Protection

Management of the airway is the first and foremost priority. A patient lying prone should be log rolled to supine position for airway assessment. Start with assessing the patency of the airway by suctioning and cleaning and look for any foreign body and facial fractures that may obstruct the airway. Management of foreign body obstruction has been summarized in **Flow chart 3.2**. However, more commonly than a foreign body, it is the tongue that falls back and obstructs the airway in the unconscious patient. Chin lift and jaw thrust **(Figs 3.2A and B)** maneuvers as outlined earlier can be performed if required to establish patency. Oropharyngeal or nasopharyngeal airways **(Figs 3.3A and B)** can be inserted if these maneuvers are not successful. Indications for definite airway management, i.e. tracheal intubation/cricothyroidotomy **(Figs 3.7A and B)** include the inability to

Flow chart 3.2: Protocol for the management of foreign body obstruction



Abbreviation: CPR, cardiopulmonary resuscitation.



Figs 3.7A and B: Cricothyroidotomy

maintain an adequate airway by abovementioned measures, the risk of aspiration or score less than 8 on Glasgow Coma Scale (GCS). Cervical spine should be manually protected all the time while managing the airway by manual in-line stabilization **(Fig. 3.8)** and neck should not be hyperflexed, hyperextended or rotated. Once the definite airway management has been done, a proper sized cervical collar is applied **(Figs 3.9A and B)**.

Breathing and Ventilation

Adequate breathing and ventilation require proper functioning of chest wall, diaphragm and lung. Chest wall should be exposed to look for the position of the trachea, symmetrical chest movements, rate and depth of respiration. Auscultate the chest for breath sounds. The most serious injuries that can compromise breathing in a polytrauma patient include tension pneumothorax, massive hemothorax and flail chest (defined as three or more contiguous rib fractures, each in two places). Oxygen is administered by high flow non-rebreathing mask. If breathing is inadequate, then BVM ventilation is started **(Fig. 3.4)**. Tension pneumothorax and massive hemothorax require immediate chest decompression **(Fig. 3.10)**.

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Fig. 3.8: Manual in-line stabilization



Figs 3.9A and B: Sizing and application of cervical collar

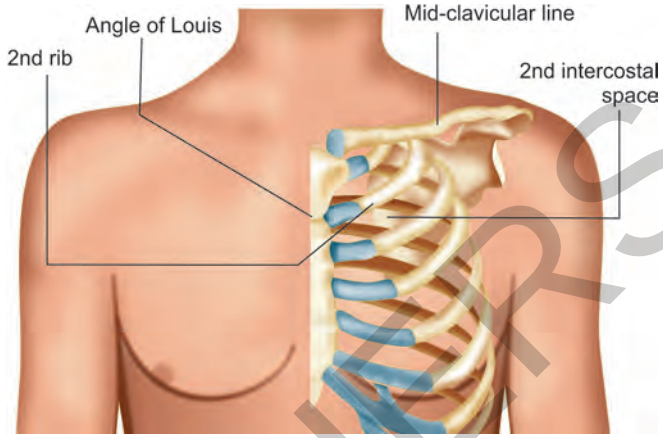

Fig. 3.10: Landmarks for needle thoracocentesis in cases of tension pneumothorax. A large bore needle is inserted in the 2nd intercostal space in mid-clavicular line to decompress the pleural space

Circulation

Control of internal and external hemorrhage is the most important preventable cause of death. Any external hemorrhage is controlled by direct pressure, wound packing or by use of a tourniquet. Internal hemorrhage may occur in the pelvis, abdomen, chest, retroperitoneum and from a fractured bone. Bleeding site is identified by clinical examination and imaging (X-ray, USG, etc.). Management depends on the site of the bleeding like pelvic binder for the hemorrhage in the pelvis and use of a splint for a fracture of a long bone and surgical packing for suspected internal bleeding. IV access is established using two wide bore cannulas placed in the antecubital fossa or groin. The patient is assessed for signs and symptoms of the shock **(Box 3.1)**. IV fluid therapy is started with crystalloid fluids, preferably 1 L (20 mL/kg) of warm (39°C) Ringer lactate (RL), titrated to patient's pulse and blood pressure response.

Disability and Neurological Examination

Level of consciousness is conventionally assessed by GCS **(Table 3.3)**. A practical approach of rapid assessment is simply asking the name or details of the accident and rating the patient as per the AVPU Scale. In AVPU scale **(Box 3.2)** after assessment, patient is assigned a letter score (A, V, P, U) based on the alertness, voice response, pain response and unresponsiveness. Patients with score below "A" level must be carefully assessed for pupillary size and reaction, signs of raised intracranial pressure and lateralizing signs and a formal GCS must be calculated. GCS less than 8 indicates a severe reduction in consciousness and such patients require urgent intubation and mechanical ventilation. Indications for neurological referral include deterioration in GCS, GCS less than 8, seizures, focal neurological signs and CSF leak. Cervical X-rays may be ordered to look for cervical spine injury while CT scan is the investigation of choice in suspected head injury cases. The criteria for imaging are given in **Table 3.4**.

Exposure and Environment Control

Undress the patient and examine the abdomen, flanks and back for any suspected injury, limb deformities and suspected fractures and dislocations. Examination of back requires "log rolling" the patient, a technique that is very critical and requires at least five team members as shown in **Figure 3.11**.

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Box 3.1: Classification of hemorrhage

- Class I: Less than 15% loss of circulating blood volume
  - *Diagnosis:* No change in blood pressure, pulse, or capillary refill
  - *Treatment:* Crystalloid
- Class II: 15–30% loss of circulating blood volume
  - *Diagnosis:* Tachycardia with normal blood pressure
  - *Treatment:* Crystalloid
- Class III: 30–40% loss of circulating blood volume
  - *Diagnosis:* Tachycardia, tachypnea, and hypotension
  - *Treatment:* Rapid crystalloid replacement, then blood
- Class IV: More than 40% loss of circulating blood volume
  - *Diagnosis:* Marked tachycardia and hypotension
  - *Treatment:* Immediate crystalloid and urgent most blood replacement

Box 3.2: AVPU Scale

A	Awake and alert patient, eyes open spontaneously
V	Patient does not open eyes spontaneously, but opens to verbal stimulation
P	Patient only responds to painful stimuli
U	Unresponsive patient

Table 3.3: Glasgow Coma Scale

Best eye opening	*Score*
Spontaneous	4
To voice	3
To pain	2
None	1
Best verbal response	
Orientated	5
Confused/disorientated	4
Inappropriate words	3
Incomprehensible sounds	2
None	1
Best motor response	
Obeys commands	6
Localizes to pain	5
Withdraws to pain	4
Abnormal flexion to pain	3
Extension to pain	2
None	1

Adjuncts to Primary Survey

These are the diagnostic and monitoring investigations which support the diagnosis of primary survey. These include: ECG, arterial blood gas analysis, pulse oximetry, insert urinary and gastric catheters, monitoring of exhaled CO_2, chest and pelvis X-rays, etc.

Table 3.4: Criteria for cervical spine imaging and CT head in polytrauma

NEXUS criteria for cervical spine imaging	*Canadian CT head rule*
No posterior mid-line tenderness	GCS < 15, 2 hours postinjury
No focal neurological deficit	Suspected depressed or open skull fracture
Normal alertness with no evidence of intoxication	Any signs of basal skull fracture (raccoon eyes, battle sign, CSF rhinorrhea, etc.)
No clinically apparent painful distracting injury	>1 episode of vomiting
	Age > 64 years
	Dangerous mechanism of injury (e.g. fall > 1 m height)
No need of cervical spine X-rays if all above conditions are met	Undertake a CT head study if any of the above condition is met

Abbreviations: NEXUS, National Emergency X-Radiography Utilization Study; GCS, Glasgow Coma Scale; CSF, cerebrospinal fluid.



- The team leader takes control of the head and cervical spine and is responsible for coordinating the roll.
- Three members of the team are positioned on the side to which the face is to be turned controlling the chest, hips and knees respectively.
- The fifth member stations on the posterior side and inspects the back as the patient is log rolled.

Fig. 3.11: Log rolling technique

Patient Transfer

Once the primary survey is done and life-threatening injuries have been identified and managed, patient transfer may be needed to a higher center or other facility in the same set-up in order to undertake appropriate investigations, to provide missing treatment or simply to provide a safer environment. It is mandatory that all such transfers, strictly be made after fixing the patient on a spine board, the same being readily available in every emergency facility **(Fig. 3.12)**.

Secondary Survey

This part involves identifying and managing non-life threatening minor injuries, which can be missed during the primary survey. Secondary survey involves taking an "AMPLE" history (Allergies,

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Fig. 3.12: Polytrauma patient being fixed to a spine board for transport

Medications currently used, Past illness/Pregnancy, Last meal, Events/Environment related to the injury), performing a detailed examination from head to toe and from front to back and reassessment of vital signs.

Secondary survey should begin only after primary survey is completed, resuscitation efforts are established and the patient is hemodynamically stable. Hemodynamic stability is defined as normal vital signs that are maintained with only maintenance fluid volumes.

Adjuncts to the Secondary Survey

These include additional X-rays, a CT scan of the head, chest, spine and abdomen, angiography, bronchoscopy, contrast urography, esophagoscopy, etc.

Definitive Care

Definitive care is the specialist treatment of the injuries, which have been diagnosed in the primary and secondary surveys.

HIGH-YIELD POINTS

- The medical algorithm for providing basic life support to adults in the USA was published in 2005 in journal "Circulation" by the AHA.
- The AHA 2015 ACLS update has advised on the use of mobile phones to notify emergency medical services (EMS) or nearby rescuers of the serious situation. The update also encourages lay persons to perform continuous "hands-only CPR" at a minimum, until the EMS arrives.
- Targeted temperature goal range of 32–36°C is advised to be maintained by AHA, during cardiac resuscitation.
- A common complication occurring during CPR is rib fractures, seen in up to one-third of the patients undergoing resuscitation. Vast majority of these fractures are bilateral and most commonly involved are anterior segments of 3rd–5th ribs. Despite fractured ribs, the doctor is supposed to continue with the CPR.
- In managing a polytrauma patient in shock, although RL, normal saline (NS) and hypertonic saline (HS), all are used world over, debate exists in context of crystalloid of choice. RL is mostly preferred, owing to the theoretical advantages it offers. RL is converted in the liver to pyruvate which is further broken down to CO_2 and H_2O. The two interact in aqueous solution to release the bicarbonate ions ($H_2CO_3 \leftrightarrow H^+ + HCO_3^-$), which act as a buffer in the setting of metabolic acidosis secondary to shock. NS on the other hand is a hyperchloremic solution (chloride ion rich fluid) that does not produce any ion that can be metabolized into HCO_3^- and hence, worsens acidosis (referred to as dilution acidosis) apart from lowering fibrinogen levels thereby increasing chances of coagulopathy. The concern using RL is the lower sodium content it has in comparison to the extracellular fluid. There is a risk of hyponatremic encephalopathy although very rare. HS on the other hand also has no proven benefit over these standard crystalloids.
- *Focused assessment with sonography for trauma (FAST):* An adjunct to surveys, this is basically a rapid bedside USG evaluation done in patients with suspected blunt trauma to the torso in order to find sites of unrecognized hemorrhage. The examination is a kind of a screening test (90% sensitivity) meant to replace historical methods like diagnostic peritoneal lavage, in searching for evidence of traumatic free fluid suggestive of bleeding into the peritoneal, pericardial or pleural cavities. The procedure involves examination of four quadrants around the abdomen (Morrison and splenorenal pouch, and around the pericardium) and the pelvis in a supine patient using 3.5–5 MHz convex USG transducers. An extended examination may also be used to evaluate the lungs for possibility of the presence of a pneumothorax (extended FAST).

MANAGEMENT OF OPEN FRACTURES

INTRODUCTION

An open fracture (old term—compound fracture) is one that communicates with external environment or in other words where the hematoma is draining out from the wound **(Fig. 3.13)**. Open fractures are orthopedic emergencies. They carry increased morbidity due to severe soft tissue injury and risk for fracture contamination. Open fractures of the tibia are the most common open long bone fractures.

CLASSIFICATION

Gustilo-Anderson classification is the most commonly used classification system for open fractures **(Table 3.5)**. Gustilo-Anderson grading must be done after debridement of the wound as the grading can change after debridement.

MANAGEMENT

Open fractures are usually high velocity injuries and patient may require resuscitation in the emergency room. Start IV antibiotics and give tetanus prophylaxis once resuscitation is complete. Active bleeding may require compression bandaging. Give IV analgesics or regional block for pain relief and remove the gross contamination. Splint the fracture, place sterile saline dressing on the wound and shift the patient to the operation theater urgently. Thorough surgical wound debridement (removal of devitalized tissue, foreign objects and any visible contamination) should be done as soon as possible (ideally within 6 hours). Vitality of muscles is assessed by *4 Cs*—color (pink), consistency (firm), contractility (should respond to pinch or electrocautery)

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and capillary circulation (actively bleeding). Patients often require serial debridements and low pressure saline lavage is the most effective way of reducing bacterial load of the wound **(Table 3.6)**. IV antibiotics should be continued for 24 hours after wound closure in Gustilo type I and type II and for 3 days in Gustilo type III fractures.



Fig. 3.13: Open or compound fracture

Table 3.5: Gustilo-Anderson classification of compound fractures*

Type/Grade	*Features*
I	Fracture wound < 1 cm with minimal soft tissue injury and fracture comminution. Usually, it is low energy trauma with clean wound
II	Fracture wound > 1 cm without extensive soft tissue damage and fracture comminution. There is mild-to-moderate soft tissue injury and mild-to-moderate wound contamination
IIIA	Fracture wound > 10 cm with extensive soft tissue injury and wound contamination, but with adequate soft tissue coverage (at least periosteum over bone is intact)
IIIB	Fracture wound > 10 cm with extensive soft tissue damage and contamination. Soft tissue coverage is inadequate (periosteal stripping occurs and bone may be exposed) and require skin or flap grafting
IIIC	Any size of open wound with major vascular injury requiring repair

*Gunshot wounds with fractures and open segmental fractures are classified as type IIIA Gustilo-Anderson injuries.

Fracture Fixation and Wound Closure

Primary definitive internal fixation of Gustilo type I fracture can be done if the soft tissue condition permits, but Gustilo type II or beyond categories, mostly need temporary external fixation (for wound management) while internal fixation is opted once infection settles and wound heals. Wound healing can be hastened by a primary closure when the soft tissue damage is limited, however, in few cases of Gustilo type II and III fractures, primary closure may not be possible and decision of closure is taken after second relook debridement. These patients often require skin grafting or coverage with muscle flaps for wound healing.

CRUSH SYNDROME (TRAUMATIC RHABDOMYOLYSIS)

INTRODUCTION

It is the systemic manifestation of extensive muscle injury due to severe crushing of muscles and subsequent release of cellular components of muscle cells into circulation. It is most commonly seen in victims of road traffic accidents with prolonged extrication.

PATHOPHYSIOLOGY

Severe crushing causes lysis of muscle cells, leading to significant metabolic derangements and eventual organ failure. The process starts with crushing and compression, opening stretch activated channels and shutting down Na/K channels at the cellular level. This leads to increased intracellular calcium, which in turn stimulates protease activity in cell leading to cellular lysis. After extrication (i.e. removal from entangled situation) restoration of blood flow to injured muscles, causes reperfusion injury. The limb may swell up rapidly leading to compartment syndrome (*see* Page 79).

Metabolic derangements include hyperkalemia, hypocalcemia and hyponatremia. With shifting of intravascular fluid into the cells, the patient frequently develops shock. Renal symptoms are the most serious complications. Myoglobin is released from damaged myocytes into circulation and precipitates into proximal tubules causing renal injury. Patients with crush syndrome are also likely to develop acute respiratory distress syndrome (ARDS) due to deregulated inflammatory mediators.

TREATMENT

It is largely supportive. Restoration of circulating blood volume to re-establish urine output and normalization of metabolic derangements are the main goals of treatment. Up to one-third

Table 3.6: Open fracture management recommendations

Type of fracture	*Infection risk*	*Prophylactic antibiotics*	*Recommended saline irrigation*	*Wound closure*
G-A type I	Increased (0–2%)	1st generation cephalosporin	With 3 liters	Usually, immediately after surgical intervention
G-A type II	Much increased (2–10%)	1st generation cephalosporin plus aminoglycoside	With 6 liters	Immediate or early (within 24–72 hours)
G-A type III	Maximum (10–50%)	1st generation cephalosporin plus aminoglycoside	With 9 liters	Immediate or early or delayed (after 72 hours)

Abbreviation: G-A, Gustilo-Anderson classification.

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of patients develop acute renal failure and require dialysis. The impending compartment syndrome may necessitate fasciotomy.

DAMAGE CONTROL ORTHOPEDICS

This relatively new concept aims at reducing mortality by advocating a temporary management of the fractures and soft tissue injury initially in a multiply injured patient till the patient is stable enough to tolerate a definitive procedure. The concept advocates that a multiply injured patient has already sustained a "hit" in the form of high energy impact during trauma. Subjecting him to "second hit" in the form of a major surgery (for definitive fracture management) when he is not too stable to bear with it may not be a rational option. Surgery itself is a kind of trauma and this second hit in an already polytraumatized patient may worsen his condition. Hence, management in multiply injured patients should be split up into emergent and definitive procedures.

The external fixator is one of the most important weapons of damage control orthopedics (DCO), in armamentarium of an orthopedic surgeon, in the care of polytrauma patients **(Figs 3.14A and B)**. It provides for rapid temporary stabilization of fractures during the early phase, reduces further tissue damage and helps in patient ambulation. Once the patient's condition is optimized (5–7 days later), definitive fixation of fractures can be undertaken.

TRAUMA SCORING SYSTEMS

INTRODUCTION

Several scoring systems are in use to classify trauma patients and to predict the outcome of multiply injured patients. These are broadly classified into anatomical, physiological and combination scores. Examples of commonly used physiological scores are revised trauma score (RTS) and acute physiology and chronic health evaluation (APACHE) score. Commonly used anatomical scores are abbreviated injury score (AIS) and injury severity score (ISS).

Following are some commonly used scores in orthopedic practice for severely injured patients:

REVISED TRAUMA SCORE

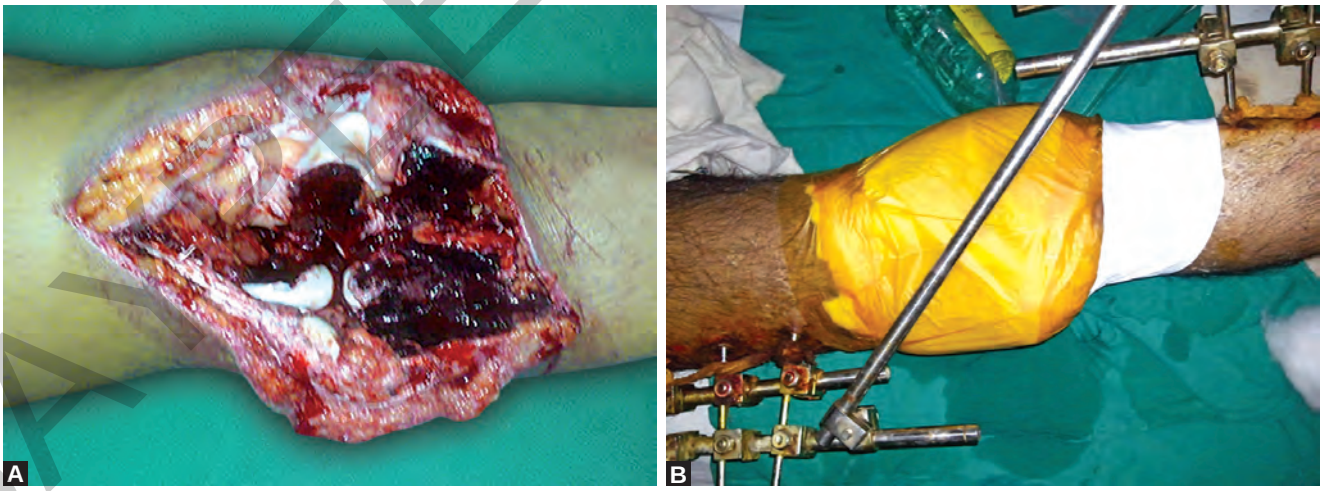
Revised trauma score is calculated from the sum of patient's respiratory rate, systolic blood pressure and GCS (GB Road*) and is used to decide which patients should be sent to a higher level trauma center. The score ranges from 0 to 12. In triage, a patient with RTS score of 12 is labeled delayed (green), 11 as urgent (yellow) and 3–10 (red) as immediate.

INJURY SEVERITY SCORE

It is an anatomical score and provides an overall score for patients with multiple injuries, helping in predicting the chances of survival. Its value is directly proportional to mortality, morbidity and hospital stay. Each injury is assigned an AIS and six body regions (head, face, chest, abdomen, extremities, including pelvis and external) are taken into consideration. Only the highest AIS score in each body region is used. The ISS score is the sum of squares of scores of three most severely injured regions. An AIS takes values between 1 and 6, and 6 is graded as unsurvivable, so the highest ISS score can be 25 + 25 + 25 = 75. If an injury is assigned an AIS of 6 (unsurvivable injury), the ISS score is automatically assigned to 75.

MANGLED EXTREMITY SEVERITY SCORE**

This score is used to predict the chances of amputation after severe extremity trauma. In cases of massive crushing of the limb, this score helps to predict whether to go for limb salvage or to



Figs 3.14A and B: External fixator being used for the initial management of multiply injured patient with open fracture (Damage Control Orthopedics) providing temporary stabilization while facilitating wound dressings

Courtesy: Dr Pradyumna Krishna M, Assistant Professor, Ortho Department, PGIMS, Rohtak.

*Mnemonic GB Road: *Glasgow coma scale, Blood pressure, Respiratory rate*
**Mnemonic LISA: *Limb ischemia, Injury severity, Shock, Age of patient*

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empirically amputate the limb to save the life of the patient. It consists of the four variables and the final score is the sum of all four variables:

1. Skeletal and soft tissue injury (graded 1–4)
2. Ischemia of limb (graded 1–3, score is doubled for ischemia of more than 6 hours)
3. Shock (graded 0–2)
4. Age (graded 0–2).

A score of 7 or more is highly predictive of amputation. It is highly specific but less sensitive score in predicting the fate of the injured limb.

HANNOVER FRACTURE SCALE (1983, UPDATED IN 1998)

Having evolved from the Tscherne's classification, the scale provides a reliable measure of limb salvage (better predictability than MES score). The scale considers every detail of the injury (extent of fracture bone loss, skin injury as a percent of limb circumference, muscle injury as a percent of limb circumference, wound contamination, deperiostation, local circulation, systolic blood pressure, neurologic findings) to the involved extremity and provides a score ranging between 0 and 22. A score more than or equal to 11 indicates significant trauma, with amputation recommended.

GANGA HOSPITAL OPEN INJURY SEVERITY SCORE (Rajasekaran, Ganga Hospital, India)

Open fractures are conventionally classified by Gustilo-Anderson classification. Gustilo classification is mainly based on the size and nature of the wound and not on the extent of the injury to the different components of the limb. Severity of the injury to different components of the limb (skin, muscles, bone, etc.) may not be related to the size of the wound. Type IIIB injuries in Gustilo classification actually include a very wide spectrum, making treatment planning rather difficult. Ganga Hospital Score was devised to ensure more uniform decision making amongst surgeons on deciding soft tissue reconstruction in such injuries. The score **(Table 3.7)** accesses three areas—skin and fascia (i.e. the covering soft tissues), the musculotendinous units (i.e. functional units) and bone (i.e. skeletal support), with the severity scale in each category ranging from 1 to 5. Further points are added if the patient has certain comorbidities. Depending on the Ganga score (calculated post-debridement) patients of type IIIB injury are grouped in 4 groups:

Group I: Score of five or less
Group II: Score between six and ten
Group III: Score of 11 to 15 and
Group IV: Score of more than 15.

Table 3.7: Ganga Hospital Open Injury Severity Score

Components	*Description*		*Scores*
Covering structures: Skin and fascia	Wound not over the bone	Without skin loss	1
		With skin loss	2
	Wound over the bone	Wounds exposing the skeleton but without skin loss and bone can be covered during debridement	3
		Wounds exposing bone due to skin loss or which require extensive debridement of the skin	4
	Wounds involving skin loss over the entire circumference of the limb exposing bone circumferentially		5
Functional tissues: Musculotendinous and nerve units	Exposed musculotendinous (MT) units without injury		1
	Injury to MT units which can be primarily repaired		2
	Crushing with loss/Irreparable injury to MT units (often involved tendon transfer) Repairable nerve injuries		3
	Extensive damage of one entire compartment MT units Irreparable nerve injuries		4
	Loss of two or more compartments/Subtotal amputation		5
Skeletal structures: Bone and joints	Transverse/Oblique fracture with periosteal stripping		1
	Unicortical comminution, presence of a large butterfly fragment involving more than 50% of the circumference or segmental fractures without bone loss		2
	Periarticular comminution with joint disorganization		3
	Circumferential comminution of bone with or without bone loss of <4 cm		4
	Comminuted/Segmental fracture with bone loss >4 cm		5
Comorbid conditions: Add 2 points for each condition present	1. Open injury >12 hours. 2. Sewage or organic contamination/farmyard injuries 3. Age >65 years 4. Debilitating diseases (DM, COPD, IHD, etc.) 5. Fat embolism 6. Associated systemic injuries 7. Another major injury to the same limb/Compartment syndrome		

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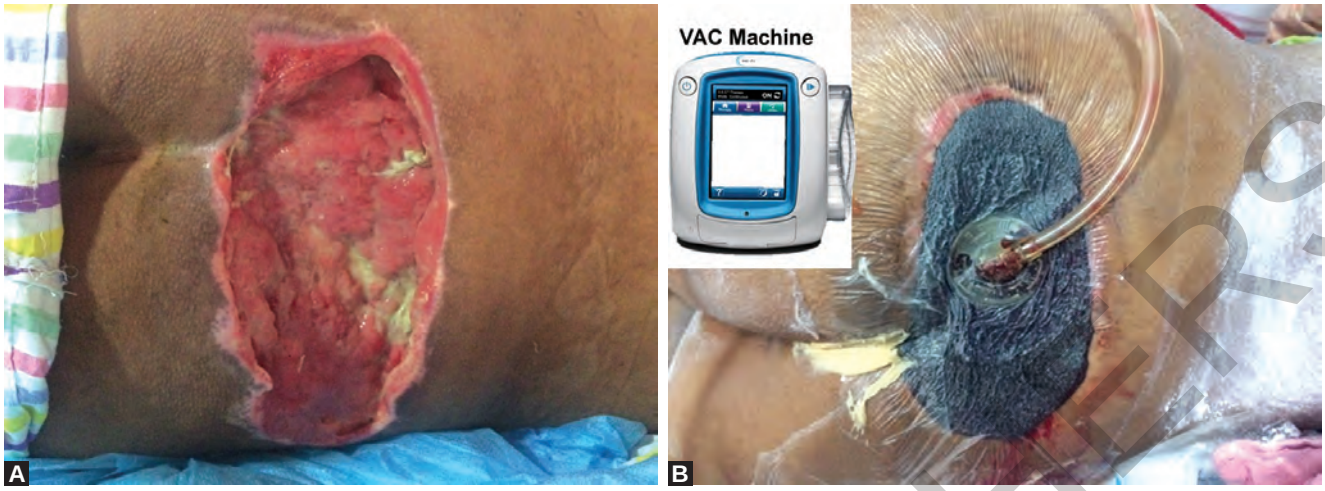

Figs 3.15A and B: (A) A nonhealing bed sore; (B) This bed sore has been debrided, dressed and sealed with a special drape. A tube from the wound has been connected to a VAC apparatus to generate negative pressure inside the wound

Courtesy: Mr. Nijo.

Score more than three in any component entails the need for plastic surgeon. Salvage is challenging and functional outcome is often guarded for a limb which gets a score of more than three in two or more components. Chances of amputation increase with increasing scores and almost all patients with a score of five in more than one component and all Group IV patients eventually require amputation.

HIGH-YIELD POINTS

- The greatest priority step in treatment of contaminated open fractures is debridement followed by external fixation. The Gustilo-Anderson classification category is also to be assigned to an open fracture, post wound debridement only.
- In grossly contaminated wounds, local antibiotic delivery may also be considered. Bead pouch technique with the use of antibiotic mixed bone cement (polymethylmethacrylate) is the commonly used method. Antibiotic impregnated cement beads are left in the wound and removed once infection settles and wound heals.
- Vacuum-assisted closure (VAC) or negative pressure wound therapy (NPWT) is a useful adjunct to wound management when primary closure is not possible. This is a sealed, negative pressure dressing applied over the wound that helps draw the wound edges together, removes infectious material by suction effect, increases local blood flow and actively promotes granulation tissue formation **(Figs 3.15A and B)**.
- *EUSOL (University of Edinburgh solution):* It is a solution made up of chlorinated lime (12.5 g) and boric acid (12.5 g) mixed in 1 L of distilled water. It is used for wound dressing as it is capable of "chemical debridement".

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