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Saudi Heart Association
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Saudi Trauma Life Support

Provider Course Manual 2025

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Saudi Heart Association

The Saudi Trauma Life Support Course (STLS) Provider Manual 2025

Preface

The Saudi Trauma Life Support Course (STLS) Provider Course is designed to equip healthcare professionals with the essential knowledge and skills required to effectively and safely manage trauma-related emergencies.

This manual aims to offer a comprehensive, consistent, and practical framework for the care of severely injured patients. While each patient may present with unique clinical signs and injuries, making it challenging to apply universal rules across all clinical scenarios, the principles outlined in this manual are grounded in safety and will provide appropriate guidance to users. It is important to recognize that the insights of an experienced consultant are invaluable, and their involvement in decision-making for complex cases is crucial.

By adopting a multidisciplinary and primarily practical approach to trauma care, this manual aspires to enhance its utility for all trauma caregivers who engage with it. Furthermore, it underscores the importance of a cohesive team-based strategy among healthcare professionals involved in both direct and indirect trauma care, aiming to improve survival rates, bolster patient safety, and positively impact health outcomes.

The manual consists of thirteen chapters, each detailing specific learning objectives and reviewing key elements. The content is tailored to the STLS course, summarizing the most recent evidence from literature and expert opinions in the field. For additional information, readers are encouraged to consult the references provided in the final chapter.

Acknowledgements

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CHAPTER ONE

Systematic Approach: Primary and Secondary Evaluation

Learning Objectives:

At the end of this chapter, the reader will be able to :

- Know how to approach the trauma patients in a systematic approach.
- Understand the components of primary and secondary evaluation.
- Recognize the importance of diagnostic procedures in primary and secondary evaluation.

Introduction

Traumatic injuries vary from minor isolated wounds to complex ones involving multiple organ systems. Every trauma patient necessitates a systematic evaluation to optimize outcomes and minimize the risk of missed injuries.

This review focuses on the primary and secondary assessment and management of adult trauma patients.

Epidemiology

Globally, trauma stands as a principal cause of mortality. Road traffic injuries are the leading cause of death among individuals aged 18 to 29 worldwide. In the United States, trauma is the foremost cause of death among young adults, contributing to 10 percent of all mortalities in both men and women. Annually, over 45 million people around the world incur moderate to severe disabilities due to trauma. Specifically, in the United States, over 50 million individuals annually seek medical care for trauma-related injuries, which constitute about 30 percent of all admissions to intensive care units (ICUs).

The World Health Organization (WHO) reports that road traffic injuries caused 1.25 million fatalities in 2014, and it is projected that trauma will become the third leading cause of disability globally by 2030. In regions without armed conflict, penetrating injuries contribute to less than 15 percent of traumatic fatalities worldwide, although this percentage differs across countries. For instance, in Los Angeles, homicides represent up to 45 percent of deaths, while in Norway, penetrating injuries constitute only 13 percent. Central nervous system (CNS) injuries account for about half of all traumatic deaths, and exsanguination is responsible for one-third.

In the Kingdom of Saudi Arabia, trauma is the leading cause of death in the first four decades of life and the primary cause of disability among the young and active population. The rate of significant trauma and related deaths has risen with the growth of the population, increased vehicle ownership, and rapid highway expansion. Motor vehicle crashes are the second leading cause of death for men and children, with an 8.5% increase in incidents from 2005 to 2016. From 2001 to 2010, MVCs accounted for 52.0% of injuries, followed by falls at 23.4%, and in 2013, MVCs led to 7,661 deaths (88% male, 12% female). In 2017, the Riyadh region alone reported over 27,000 MVC-related emergency room admissions and over 120,000 admissions for non-MVC trauma, highlighting the magnitude of the issue.

Table 1.1: Injuries and deaths from Road traffic Accidents in the last 10 year

Deaths per 100,00 population	Injuries per 100,00 population	No. of Deaths	No. of Injuries	Year
26.44	126.61	7,486	35,843	2014
27.04	121.75	8,063	36,302	2015
28.30	123.15	8,759	38,120	2016
23.30	107.17	7,218	33,199	2017
19.16	100.07	5,787	30,217	2018
19.14	109.47	5,754	32,910	2019
14.64	81.01	4,618	25,561	2020
15.11	82.87	4,652	25,512	2021
14.16	75.98	4,555	24,446	2022
13.06	70.87	4,423	24,002	2023
Source: The Ministerial Committee of Traffic Safety				

Patients suffering from severe traumatic injuries are more likely to survive and recover when treated at a specialized trauma center. Factors such as advanced age, obesity, and significant comorbidities contribute to poorer outcomes after trauma. Additionally, in cases of substantial hemorrhage, a lower Glasgow Coma Scale (GCS) score and increased age are independently linked to a higher risk of mortality.

The most common causes of death from trauma are hemorrhage, multiple organ dysfunction syndrome, and cardiopulmonary arrest, while the most common preventable causes of morbidity include unintended extubation, surgical technical failures, overlooked injuries, and complications related to intravascular catheters.

Some patients die after the initial 24 hours post-injury. Instead, most deaths occur either at the scene or within the first four hours after arrival at a trauma center.

The concept of the "golden hour" highlights the critical need for swift intervention within the first hour after major trauma, as early trauma studies have shown an increased risk of death during this period. This concept is widely taught and referenced. While rapid response can indeed be life-saving in cases such as airway obstruction, tension pneumothorax, or severe bleeding—particularly in battlefield scenarios—the exact relationship between the timing of care and mortality is likely more intricate than previously believed.

Mechanism

Specific mechanisms predispose patients to particular injuries. The accompanying table outlines common blunt trauma mechanisms and their most frequently associated injuries. Moreover, certain high-risk blunt mechanisms, such as pedestrians hit by vehicles, motorcycle crashes, severe motor vehicle collisions (e.g., extensive damage resulting in prolonged extrication time), and falls from heights greater than 20 feet, are linked to increased morbidity and mortality.

Table 1.2: Blunt trauma mechanisms and associated injuries
Motor vehicle collisions

Mechanism of injury	Additional considerations	Potential associated injuries
Head-on collision		• Facial injuries • Lower extremity injuries • Aortic injuries
Rear-end collision		• Hyperextension injuries of cervical spine • Cervical spine fractures • Central cord syndrome
Lateral (T-bone) collision		• Thoracic injuriesAbdominal injuries (spleen, liver), Pelvic injuries • Clavicle • humerus • rib fractures
Rollover	Greater chance of ejection, Significant mechanism of injury	• Crush injuries • Compression fractures of spine
Ejected from vehicle	• Likely unrestrained • Significant mortality	Spinal injuries
Windshield damage	Likely unrestrained	• Closed head injuries, coup and contrecoup injuries • Facial fractures • Skull fractures • Cervical spine fractures
Steering wheel damage	Likely unrestrained	Thoracic injuries • Sternal and rib fractures • flail chest • Cardiac contusion • Aortic injuries • Hemo/pneumothoraces
Dashboard involvement/damage		Pelvic and acetabular injuries, Dislocated hip

Table 1.3 Restraint/seat belt use

Mechanism of injury	Additional considerations	Potential associated injuries
Automobile related		Closed head injuries, "Handlebar" injuries (Spleen/liver lacerations, Additional intra-abdominal injuries, Consider penetrating injuries)
Nonautomobile related		Extremity injuries, "Handlebar" injuries

Table 1.4 Bicycle

Mechanism of injury	Additional considerations	Potential associated injuries
Proper three-point restraint	Decreased morbidity	• Sternal and rib fractures • pulmonary contusions
Lap belt only		Chance fractures, abdominal injuries, head and facial injuries/fractures
Shoulder belt only		Cervical spine injuries/fractures, "submarine" out of restraint devices (possible ejection)
Airbag deployment	• Front-end collisions • Less severe head/upper torso injuries • Not effective for lateral impacts • More severe injuries in children (improper front seat placement)	Upper extremity soft tissue injuries/ fractures Lower extremity injuries/fractures

Table 1.5 Falls

Mechanism of injury	Additional considerations	Potential associated injuries
Vertical impact	LD50 36 to 60 feet (11 to 18 m)	Calcaneal and lower extremity fractures, Pelvic fractures, Closed head injuries, Cervical spine fractures, Renal and renal vascular injuries
Horizontal impact		Craniofacial fractures, Hand and wrist fractures, Abdominal and thoracic visceral injuries, Aortic injuries

Preparation

Pre-arrival preparation is crucial. Whenever feasible, emergency medical services (EMS) should inform the destination hospital of an incoming trauma patient. This advance notice is vital for the hospital to manage a severely injured patient effectively.

The information EMS should ideally provide includes:

- The patient's age and gender
- The injury mechanism
- Vital signs (clinicians often request the lowest recorded blood pressure and highest pulse)
- Observed injuries

Such early notification allows the emergency department (ED) staff to:

- Call additional personnel (such as ED staff, trauma surgeons, obstetricians, orthopedists, radiologists, and interpreters)
- Ensure necessary resources are ready (like ultrasound, CT scans, and operating room availability)
- Set up for expected procedures (like endotracheal intubation and chest tube insertion)
- Arrange for blood transfusions

Moreover, information relayed by EMS before arrival can assist hospital clinicians in concentrating on the most probable injuries. For instance, a report of a feet-first fall from a significant height suggests the possibility of fractures in the calcaneus, lower extremities, and lumbar spine; in the same vein, a prolonged extrication from a motor vehicle due to the collapse of the driver's side compartment may indicate potential injuries like rib fractures, pulmonary contusion, and spleen and kidney lacerations.

As part of their preparation, the trauma team should adhere to universal precautions against diseases transmitted through blood and bodily fluids. This includes the use of gloves, gowns, masks, and eye protection by all team members participating in the resuscitation. Additionally, lead shields should be accessible for staff if portable x-rays are anticipated during the resuscitation process.

In rural hospitals, trauma teams often consist of just a physician and a nurse. They may call upon EMS personnel or other clinicians for assistance with critically ill or numerous patients. At major trauma centers, teams are larger, including emergency physicians, trauma surgeons, specialist surgeons, emergency nurses, respiratory therapists, technicians, and social workers. Every team, regardless of size, requires a designated leader to oversee the management plan and delegate tasks. Leaders in smaller settings may perform procedures themselves, while those in larger settings should focus on supervisory duties to monitor the patient's condition closely.

Effective communication and teamwork are crucial for the optimal care of trauma patients, regardless of the team's composition. Quality care starts with a briefing before the patient's arrival, assigning roles and tasks, and continues with closed-loop communication during resuscitation, ensuring everyone shares the same care plan vision. It's also vital to keep the conscious patient or their health care proxy informed about the care plan and any updates.

Breakdowns in care plans and medical mismanagement often stem from one or more of four potential issues:

- Communication breakdowns, such as ineffective communication of changes in a patient's physiological state or critical test results, or unclear conveyance of the overall management plan or task priorities by the team leader.
- Failures in situational awareness, including not recognizing shock, not anticipating the need for blood transfusions, or not adjusting standard management for higher-risk patients.
- Staffing or workload distribution problems, like having insufficiently trained staff perform procedures or inadequate staffing levels for the patient volume.
- Unresolved conflicts, for instance, ongoing hostility towards team members perceived as underperforming, disagreements over the management plan, or disputes among senior clinicians competing for team leadership.

Primary Evaluation and Management

Key principles and a systematic approach are crucial when managing a severely injured patient. The Saudi Advanced Trauma Life Support (ATLS) advocates for a clear, simple, and organized method. The primary survey, structured according to the most immediate life-threatening injuries, should be conducted in the sequence outlined below. In resource-limited settings, the primary survey streamlines priorities, with any identified issues being addressed immediately before proceeding. In contrast, at major trauma centers, the presence of numerous skilled clinicians allows for the simultaneous management of multiple issues.

The primary survey includes:

- **Airway**: Assess and protect, maintaining cervical spine stabilization as needed.
- **Breathing**: Assess ventilation and ensure adequate oxygenation.
- **Circulation**: Assess and control hemorrhage, maintaining sufficient end-organ perfusion.
- **Disability**: Conduct a basic neurological evaluation.
- **Exposure**: Fully assess the patient for injuries, managing environmental factors to prevent hypothermia.

Consider these points during the primary survey:

- Airway obstruction is a leading cause of immediate post-trauma mortality. Obstructions may be due to the tongue, foreign objects, aspirated substances, tissue swelling, or expanding hematomas.
- Tracheal intubation guidelines in trauma are not definitive. Early intubation is advisable for significant facial or neck injuries that could cause airway distortion due to swelling. In hemodynamically unstable cases, it may be preferable to postpone intubation until physiological conditions have been stabilized, as rapid sequence intubation drugs may worsen hypotension.
- Caution with pneumothorax in unconscious patients – Small pneumothoraces in unconscious patients may not be apparent on initial chest X-rays and can lead to tension physiology following tracheal intubation due to positive pressure ventilation. It's crucial to re-examine the lungs of trauma patients who show signs of hemodynamic instability after intubation and to heed ventilator pressure alarms.
- Diligently identify hemorrhage – Hemorrhage is a leading preventable cause of death in trauma patients. Watch for subtle indicators of hemorrhagic shock, especially in the elderly on cardiovascular medications that may mask symptoms, and in young, healthy individuals who may not exhibit clear signs early on. Hypotension often does not appear until a patient has lost at least 30 percent of their blood volume, placing them at significant risk of death. Elderly patients may exhibit hypotension compared to their usual blood pressure yet remain within "normal" ranges. Any instance of hypotension greatly increases the chance of a severe injury.
- Manage hypotension in brain injury – Brain injuries are prevalent in severe blunt trauma cases, and a single occurrence of hypotension can significantly elevate the risk of mortality.

Airway

Airway management is crucial for severely injured patients, as they may develop airway obstruction or inadequate ventilation, which can lead to hypoxia and death within minutes. Airway obstruction is a significant cause of preventable death in trauma patients. Consequently, evaluating and managing the airway is the essential first step in treating any severely injured patient.

Multiple studies indicate that using checklists can enhance the efficiency and decrease the complications related to the airway management of trauma patients. An example checklist is included in the accompanying table.

Pre-arrival checklist in preparation for airway management of adult trauma patient
• Oxygen mask and nasal cannula available and connected to oxygen
• Bag-valve mask with $ETCO_2$ attachment available
• Oral airways available
• Suction available and working
• Direct laryngoscope handle and blades available and functional (light works)
• Tracheal tubes (multiple sizes) and stylet available; tube shaped straight to cuff
• Tracheal tube introducer ("bougie") available
• Rescue airway devices available (e.g., laryngeal mask airway, King airway)
• Cricothyrotomy kit available
• Video laryngoscope available; monitor positioned appropriately
• IV catheters and isotonic fluids available
• Individuals designated to provide cervical spine stabilization and airway assistance
• Airway plan verbalized (primary plan and back-up plan)
• Respiratory therapist notified; mechanical ventilator brought to bedside
Pre-induction checklist for intubation of adult trauma patient
• Pre-arrival checklist completed
• Airway plan confirmed between trauma and ED attending physicians (if necessary)
• IV lines functioning
• Induction and NMBA medications and doses confirmed, and drawn up in labeled syringes
• Cervical spine stabilization initiated (if necessary)
• Pre-oxygenation underway: mask at 15 L/minute and nasal cannula at 5 L/minute
• Patient positioning optimized
• Blood pressure cuff placed on arm opposite that of IV line and pulse oximetry probe

Table 1.6 A preprocedural checklist of intubation of adult trauma patient

Abbreviations: $ETCO_2$: End-tidal carbon dioxide
IV: Intravenous
NMBA: Neuromuscular blocking agent
ED: Emergency department
Note: All items must be verbalized by the Nurse Scribe and confirmed by the physician or clinician responsible for airway management.

Source: Adapted from Smith KA, High K, Collins SP, Self WH. A preprocedural checklist improves the safety of emergency department intubation of trauma patients. Acad Emerg Med 2015; 22:989.

Positioning the patient's stretcher at a slight incline, with the head elevated (reverse Trendelenburg position), or raising just the head to approximately 30 degrees when cervical spine precautions are not necessary, can reduce the risk of aspiration and enhance lung capacity by lessening abdominal pressure on the diaphragm.

Assessment — For a conscious patient, the initial airway assessment may include:

- Asking the patient a simple question (e.g., "What is your name?") to verify their cognitive function, speech clarity, and airway protection capabilities, albeit temporarily.
- Observing the face, neck, chest, and abdomen for signs of respiratory distress, such as rapid breathing, use of accessory or uneven muscles, irregular breathing patterns, and stridor.
- Examining the oropharyngeal cavity for any disruptions; damage to teeth or tongue; presence of blood, vomit, or accumulated secretions. It's important to note any impediments to the insertion of a laryngoscope and endotracheal tube.
- Inspecting and feeling the anterior neck for cuts, bleeding, crepitus, swelling, or other injury indicators. Palpating the neck also helps in locating the landmarks necessary for a cricothyrotomy.

In an unconscious patient, immediate protection of the airway is crucial once obstructions such as foreign bodies, vomitus, or a displaced tongue are cleared. The overall management of the airway, and specifically in cases of direct trauma, is addressed in a separate discussion.

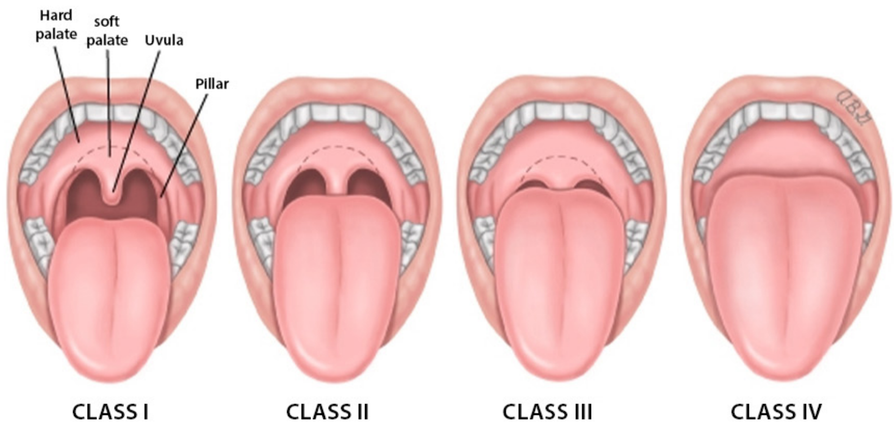
For a trauma patient who cannot protect their own airway, management must be swift yet methodical. If feasible, a brief pre-intubation assessment should be conducted to evaluate the potential challenges of intubation and to assess basic neurological functions, such as the pupillary light reflex and limb movement. While methods and mnemonics for assessing the difficulty of airway management are discussed elsewhere, the use of the LEMON mnemonic in trauma patients is outlined here.

- **L: LOOK:** Injuries to the face and neck may alter both external and internal structures, complicating the visualization of the glottis or the insertion of an endotracheal tube.
- **E: EVALUATE 3-3-2:** This evaluation involves assessing the distances within the mouth, between the mandible, and from the hyoid bone to the thyroid notch. To accurately assess these, the cervical collar should be loosened. These distances may be reduced due to fractures, hematomas, or other anatomical changes, such as swelling of soft tissues.

- **M: MALLAMPATI:** In many trauma patients, a standard calculation of the Mallampati score is not feasible; those requiring emergency intubation often cannot open their mouths voluntarily. However, it is still crucial to attempt to assess the visibility of the retropharynx and to check for any injuries of the oropharynx or the presence of pooled blood, vomitus, or secretions.

The Modified Mallampati Classification for Difficult Laryngoscopy and Intubation

THE MODIFIED MALLAMPATI CLASSIFICATION FOR DIFFICULT LARYNGOSCOPY AND INTUBATION



he modified Mallampati classification is a simple scoring system that relates the amount of mouth opening to the size of the tongue and provides an estimate of space available for oral intubation by direct laryngoscopy. According to the Mallampati scale:

Class I: The soft palate, uvula, and pillars are visible.

Class II: The soft palate and the uvula are visible.

Class III: Only the soft palate and base of the uvula are visible.

Class IV: Only the hard palate is visible.

- **O: OBSTRUCTION/OBESITY:** Both factors can hinder the visualization and management of a traumatized airway. A variety of injuries, such as internal or external hematomas or soft tissue swelling from smoke inhalation, can obstruct the airway. Additionally, obesity can make performing a cricothyrotomy more challenging.

- **N: NECK MOBILITY:** In-line stabilization is crucial for most trauma patients. After a second trained provider removes the cervical collar, they must stabilize the spine during orotracheal intubation. It's critical to understand that the risk of neurological damage from hypoxemia far outweighs the risk of spinal injury from neck extension during intubation. In certain situations, a careful easing of immobilization may be required.

Difficult airway devices

Several airway tools and rescue airways are beneficial in managing a trauma patient. Devices that ought to be readily available at the bedside encompass:

- Suction (ie, multiple pumps and tips)
- Bag-valve mask attached to high flow oxygen
- Oral and nasal airways
- Rescue airways (eg, Combitube, Laryngeal mask airway)
- Endotracheal tube introducer (ie, gum elastic bougie)
- Video laryngoscope, if available
- Cricothyrotomy kit
- Endotracheal tubes in a range of sizes
- Laryngoscopes, including a range of different sized blades and handles
- Preferred adjunct intubating devices (eg, lightwand)

Direct laryngoscopy depends on the direct visualization of the glottis, which can be challenging in severely injured patients with obstructed airways and restricted neck movement. In contrast, video laryngoscopes offer an excellent view of the glottis with minimal cervical spine movement, making them suitable for airway management in trauma patients. A review of over 4,000 trauma intubations at 23 emergency departments from 2016 to 2018 showed that video laryngoscopy had a significantly higher first-pass success rate (90% versus 79%) and lower esophageal intubation rates (0.4% versus 1.5%) compared to direct laryngoscopy.

The endotracheal tube introducer, also known as the gum elastic bougie, is an indispensable tool for managing the airways of trauma patients, especially when the view of the glottis is restricted.

Intubation — Tracheal intubation in injured patients is often complicated by the need for cervical immobilization, the presence of obstructions like blood, vomit, and debris, and potentially direct trauma to the airway. Despite these challenges, many trauma patients need intubation for immediate airway protection or due to the anticipated progression of their condition. Intubation enhances oxygenation, meeting increased physiological demands, and facilitates testing and procedures with reduced patient discomfort.

Airway managers should ideally have a pre-established backup plan with all essential tools at hand, including rescue airways and a cricothyrotomy kit, before attempting intubation. However, in emergency situations, this may not be feasible. An example checklist to aid in the airway management of the adult trauma patient is provided in the accompanying table.

Table 1.7: Glasgow Coma Scale (GCS)

Category	Score
Eye Opening	
Spontaneous	4
Response to verbal command	3
Response to pain	2
No eye opening	1
Best Verbal Response	
Oriented	5
Confused	4
Inappropriate words	3
Incomprehensible sounds	2
No verbal response	1
Best Motor Response	
Obeys commands	6
Localizing response to pain	5
Withdrawal response to pain	4
Flexion to pain	3
Extension to pain	2
No motor response	1
Total	

Abbreviations:
ETCO2: End-tidal carbon dioxide
IV: Intravenous
NMBA: Neuromuscular blocking agent
ED: Emergency department

All items must be verbalized by the Nurse Scribe and confirmed by the physician or clinician responsible for airway management.

Clinicians must evaluate the anticipated progression of disease and the necessity for interventions when deciding on airway management. Early intubation is often justified to protect the airway or to facilitate deeper sedation and pain management. For instance, a patient who is currently hemodynamically stable but at risk of decline and requires a complex diagnostic procedure in a distant radiology suite; or a patient with severe injuries who urgently needs an orthopedic or another painful intervention. Critically ill trauma patients, who are at risk of hypotension after sedation and paralysis for intubation, should receive proactive treatment. The possibility of hypotension after intubation should be expected and reduced as much as possible. A retrospective analysis of 444 patients showed that in-hospital mortality almost doubled for those who experienced a single instance of post-intubation hypotension compared to those who did not (29.8% versus 15.9%). [].

Techniques for airway management in trauma, such as rapid sequence intubation, rescue airways, video laryngoscopy, and direct laryngoscopy, are elaborated on in separate chapters.

Cricothyrotomy — Clinicians managing trauma should be ready to perform a cricothyrotomy when orotracheal intubation is not possible.

For trauma patients with a potentially difficult airway, a dual set-up for orotracheal intubation and cricothyrotomy may be advisable. This strategy allows clinicians to swiftly switch to cricothyrotomy if orotracheal intubation fails.

Injuries to the neck in trauma patients can complicate cricothyrotomy, making it crucial to make every effort to optimize orotracheal intubation.

Cervical spine immobilization — In all cases of blunt trauma, it is essential to presume a cervical spine injury until ruled out. On the other hand, patients with isolated penetrating trauma, without any secondary blunt injury and a normal linked to higher mortality rates. Moreover, it is not necessary for airway neurological examination, usually do not sustain an unstable spinal column injury. Routine spinal immobilization is not advised after penetrating trauma as it is management in patients with penetrating neck trauma.

For patients with blunt traumatic injuries undergoing airway interventions, including bag-mask ventilation, the anterior part of the cervical collar should be temporarily removed while maintaining manual in-line stabilization. Airway interventions prior to intubation can cause as much spinal column subluxation as the intubation itself.

Tracheal intubation should never be performed with the anterior part of the cervical collar in place. Intubations carried out with the entire cervical collar are associated with more significant spinal subluxation compared to those done with the anterior part removed and manual in-line stabilization.

The effectiveness of manual in-line stabilization in patients with blunt traumatic injuries who require intubation is well documented and established.

Breathing and ventilation — After ensuring airway patency, it's crucial to evaluate oxygenation and ventilation adequacy. Chest trauma contributes to approximately 25 percent of deaths related to trauma, primarily due to its detrimental impact on oxygenation and ventilation.

Examine the chest wall for injury signs, such as asymmetric or paradoxical movement (e.g., flail chest), listen to breath sounds at the apices and axillae, and feel for crepitus and deformity. For unstable patients, acquire a portable chest X-ray. Life-threatening conditions like tension pneumothorax, massive hemothorax, and cardiac tamponade should be identified during this primary survey phase. Ultrasound can yield vital information about these conditions at this assessment stage.

Circulation

Recognition and management of hemorrhage — After stabilizing the airway and breathing, assess the patient's circulatory status by checking central pulses. If a carotid or femoral pulse is present and strong and there's no significant external bleeding, assume circulation is adequate; don't delay the primary survey for an exact blood pressure reading.

During circulation assessment, insert two large-bore (16 gauge or larger) IV catheters, typically in the antecubital fossa of each arm, and draw blood for typing and crossmatch. If peripheral IV access is challenging, consider intraosseous cannulation or central venous catheter placement, ideally with ultrasound guidance.

Control life-threatening hemorrhage immediately. Use manual pressure, proximal compression with a tourniquet or blood pressure cuff, and elevation to manage external arterial bleeding. If ineffective, apply hemostatic agents when available. Direct pressure can control venous bleeding. Severe pelvic injuries may need a pelvic binder.

For trauma patients lacking femoral or carotid pulses, an emergency thoracotomy may be necessary. This is most effective for chest stab wound victims who initially show signs of life, such as voluntary movement. It's less beneficial for blunt trauma or without immediate surgical support. Notably, trauma patients needing CPR within one hour of hospital arrival have a low survival rate to discharge, making it crucial to maintain perfusion and prevent the need for CPR.

In critical patients nearing cardiac arrest, the deployment of a Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA) by trained professionals can be lifesaving. This device is particularly effective in stabilizing patients with hemorrhage from intra-abdominal or retroperitoneal injuries until they can undergo definitive surgical or angioembolic treatment. Therefore, swift transportation to an operating room or angiographic suite is crucial. However, REBOA is not suitable for patients with suspected thoracic hemorrhage or those in cardiac arrest, where a resuscitative Emergency Department Thoracotomy (EDT) is the preferred intervention.

Most trauma patients exhibiting hypotension or shock symptoms, such as pale, cool, and moist skin, are experiencing bleeding. Those with severe hemorrhage face a significantly increased risk of mortality. Initial fluid resuscitation might include a bolus of intravenous crystalloid, like 20 mL/kg isotonic saline. However, patients with clear signs of severe or continuous blood loss should receive an immediate transfusion of type O blood, with O negative blood reserved for women of childbearing potential. The strategies for fluid resuscitation, including the judicious use of delayed fluid resuscitation and blood transfusion for trauma patients in shock, are topics for separate discussion.

Patients with persistent hemodynamic instability, despite receiving an initial fluid bolus, often need a blood transfusion and definitive control of the bleeding source. Significant bleeding can occur in any of the following five sites:

- External
- Intrathoracic
- Intraperitoneal

- Retroperitoneal
- Pelvic or long bone fractures

In cases where transfusion is necessary, administer whole blood or blood components in a 1:1:1 ratio of plasma, platelets, and red cells. Patients who require transfusion may also benefit from tranexamic acid treatment if administered within three hours of the injury. The management of blood transfusion in trauma patients and the application of antifibrinolytic agents like tranexamic acid are further discussed in separate detailed sections.

Reversal of anticoagulation — Some trauma patients, particularly elders with comorbidities, may be taking anticoagulants.

Nonhemorrhagic causes of shock — In adult trauma patients, shock can arise from nonhemorrhagic causes such as tension pneumothorax and cardiac tamponade. These conditions are optimally identified through physical examination or ultrasound assessment, for instance, the FAST exam. It is especially important in older patients for clinicians to evaluate for medical conditions that may have led to hypotension and contributed to the trauma, including myocardial infarction, arrhythmia, a malfunctioning pacemaker or left ventricular assist device (LVAD), or gastrointestinal bleeding.

Disability and neurologic evaluation — After addressing any issues with the airway, breathing, and circulation, conduct a detailed neurological examination. This examination should encompass an evaluation of the patient's consciousness level using the Glasgow Coma Scale (GCS), along with assessments of pupil size and response, overall motor function, and sensory perception. Additionally, observe for any lateralizing signs and determine the sensation level if there is a suspected spinal cord injury.

The Glasgow Coma Scale (GCS) score is commonly utilized to monitor a patient's neurological status. However, several studies indicate that the initial GCS score may not predict outcomes in patients with severe brain injuries, and factors such as intubation, sedation, and intoxication from alcohol or drugs can impede its effectiveness.

It is crucial to maintain spinal immobilization in patients who may have sustained a spinal cord injury. The existence of a motor deficit or a sensory level indicative of spinal cord involvement necessitates imaging of the brain, spinal cord, and their associated vasculature.

Exposure and environmental control — Ensure that the trauma patient is fully undressed and their entire body is checked for injuries during the primary survey. Overlooked injuries are a serious concern. Commonly missed areas include the scalp, axillary folds, perineum, and, in obese patients, the abdominal folds. Penetrating wounds can occur anywhere. While taking cervical spine precautions, thoroughly examine the patient's back, including the gluteal fold and posterior scalp.

Preventing hypothermia is crucial and should be treated as soon as it's detected. Hypothermia can lead to coagulopathy and multiple organ dysfunction syndrome. In cold weather and when treating a hypothermic trauma patient, the resuscitation room must be warmed. The United States Military Joint Theater Trauma System Clinical Practice Guideline for hypothermia prevention advises that emergency department (ED) and operating room (OR) temperatures be at least 29.4°C (85°F) for these patients. Remove wet clothing quickly, use warm blankets and active external warming devices generously, and heat IV fluids and blood. Separate guidelines exist for treating hypothermia.

Diagnostic studies

Portable radiographs — Plain radiographs are crucial in the initial assessment of unstable trauma patients. Screening radiographs ought to be taken, whether in the emergency department (ED) or the operating room (OR), even if patients are hemodynamically unstable and are taken directly to the OR during or after their primary survey. Immediate imaging of thechest, and pelvis is vital to identify potentially life-threatening injuries that may be overlooked.

For trauma patients not expected to need CT imaging, plain radiography of the chest and pelvis is often performed. The decision to acquire these images should be based on the mechanism of injury and clinical observations. Patients with penetrating trauma are frequently assessed with images of the affected area; these radiographs can identify retained foreign bodies or fragments, even in stable patients. Conversely, patients with blunt trauma should only have plain radiograph imaging if clinical signs indicate an injury. If there is no clinical indication of injury and the radiographs are not expected to change emergency management, they can be skipped.

Patients with penetrating injuries to the chest, back, or abdomen should have a plain chest radiograph, regardless of CT requirements. These films can detect subdiaphragmatic free air, foreign bodies, or conditions such as pneumothorax or hemothorax.

When a clinician decides that CT imaging is necessary based on the mechanism or clinical suspicion, plain radiographs of the chest or pelvis serve no role in the assessment of hemodynamically stable patients with blunt trauma.

Ultrasound (FAST exam) — The Focused Assessment with Sonography for Trauma (FAST) is a crucial component of the primary circulatory survey in unstable patients, often guiding their management. FAST's primary use is to identify pericardial and intraperitoneal bleeding, proving more accurate than any physical examination in detecting signs of intra-abdominal injury. In patients who are hemodynamically stable, the FAST examination can be postponed until the secondary survey and should ideally be conducted by a second operator as the rest of the secondary survey proceeds.

However, the effectiveness and applicability of FAST may be diminished in patients with significant pelvic fractures, as it is less sensitive in detecting pelvic hemorrhage and cannot distinguish between blood and urine. Additionally, ultrasound does not reliably visualize retroperitoneal bleeding.

The Focused Assessment with Sonography for Trauma (FAST) is less sensitive to injuries from penetrating trauma compared to blunt trauma. Therefore, ultrasound examination results, especially negative ones, should be interpreted cautiously in patients with penetrating trauma.

The Extended FAST (E-FAST) expands the examination to the thoracic cavity to detect pneumothoraces. Initial studies indicate that the sensitivity of E-FAST may surpass that of plain radiography for this type of injury.

Emergency computed tomography (CT) — During the primary survey, trauma patients who are hemodynamically unstable undergo aggressive resuscitation as clinicians work to identify the most likely causes of their instability. If the source of bleeding in an unstable trauma patient cannot be pinpointed with diagnostic imaging studies available at the bedside, or if more information is necessary to guide surgical care, the emergency physician and surgeon often must choose between conducting emergency CT imaging first or proceeding directly to the operating room. This decision hinges on the patient's reaction to initial resuscitation, their potential injuries, expected surgical procedures, and how close the CT scanner is to the resuscitation area.

In scenarios where patients need a higher level of care than the initial facility can provide, imaging should not postpone the transfer. The transfer process should begin as soon as feasible, sometimes immediately after the patient's arrival and evaluation. If CT imaging is required and can be performed safely and without delaying the transfer, it should be done.

On occasion, patients may present with known and potentially life-threatening allergies to IV contrast. In these instances, alternative diagnostic methods may be considered, such as non-contrast CT, ultrasound, exploratory surgery, and, if the patient's condition and available resources permit, MRI.

Diagnostic peritoneal tap or lavage — Diagnostic peritoneal tap (DPT) or lavage (DPL) serves a purpose akin to FAST for unstable patients whose bleeding source remains unidentified. It is utilized to detect intraperitoneal blood when FAST is not accessible or inconclusive, especially in hemodynamically unstable patients. It also helps ascertain the nature of intraperitoneal fluid—such as distinguishing between blood and urine in cases of pelvic fracture—or can be performed at the physician's discretion.

Electrocardiogram — An electrocardiogram (ECG) is recommended for all patients who have sustained injuries that could potentially cause cardiac harm. Signs indicative of blunt cardiac injury may encompass arrhythmias, notable conduction delays, or alterations in the ST segment. Symptoms aligned with pericardial tamponade are tachycardia, diminished voltage, and electrical alternans. Should ECG results suggest cardiac injury, a comprehensive echocardiography should be conducted alongside the FAST examination. Moreover, continuous cardiac monitoring is advised throughout the trauma assessment and resuscitation process, including any diagnostic tests, since fluctuations in heart rate and blood pressure can signal an impending clinical decline.

Laboratory tests — Routine "screening" laboratory tests for trauma patients are generally neither useful nor cost-effective. Testing should be based on clinical suspicion and limited to tests that could change management. For instance, women of childbearing age should always have a pregnancy test (e.g., urine hCG), and patients with significant trauma who might need a transfusion should have a blood type and screen or crossmatch.

The necessity for additional testing is dictated by clinical circumstances. For example, patients on warfarin may require coagulation studies (e.g., prothrombin time), and patients discovered on the ground for an unknown duration may need tests (e.g., creatine kinase) to check for rhabdomyolysis.

Initially, the decision to transfuse blood products in severely injured trauma patients is made clinically, which may include massive transfusion protocols. Subsequent routine coagulation studies are not accurate predictors of coagulopathy in acute trauma patients; thromboelastography (TEG), when available, offers a quicker and more precise method to detect hemostatic imbalances and to evaluate the need for ongoing treatment.

Tests that are commonly performed but often unhelpful include the metabolic panel (a fingerstick blood sugar may suffice if there are no signs of electrolyte imbalance or acidosis), alcohol level in an obviously intoxicated patient, toxicologic screen when it's irrelevant to clinical care, and cardiac biomarkers, unless there's suspicion of cardiac contusion or ischemia.

An increase in serum lactate concentration and base deficit is associated with higher mortality in trauma patients. However, base deficit alone is a surrogate for lactate and does not predict increased mortality without an accompanying rise in lactate. Elevated levels can indicate severe injury, but normal lactate and base deficit levels do not rule out significant injury, particularly in elderly trauma patients. Moreover, lab values may not immediately reflect clinical improvement following aggressive resuscitation, so a patient may not be in shock even if lactate levels remain high.

The white blood cell (WBC) count is a nonspecific test with limited value in the initial assessment of a trauma patient. Both elevated and normal WBC counts have poor predictive value. Trauma-induced epinephrine release can cause demargination, potentially raising the WBC count to 12,000 to 20,000/mm3 with a moderate left shift. Injuries to solid or hollow organs can also lead to similar increases.

Patient Transfer

Clinicians at hospitals with limited resources for trauma management should immediately consult the nearest trauma center when a patient's injuries exceed the hospital's capacity. Despite the need for transfer for trauma evaluation, many patients remain unsent.Non-transferred patients had higher risk-adjusted mortality rates compared to those treated at level I or II trauma centers. An example of this issue is geriatric trauma patients, who are often under-triaged, leading to higher morbidity and mortality.

Patients should be stabilized as much as possible without delaying transfer, as delays are linked to increased mortality. Transfer criteria depend on the patient's demographics, injury mechanism, and clinical findings. It's crucial to understand that a complete workup isn't necessary for transfer; delaying for lab results or imaging studies postpones definitive care. Such studies are often repeated at the receiving facility anyway.

CT imaging should be reserved for patients who could be adequately treated at the initial facility. If a negative CT scan would lead to discharge, it should be done; however, if transfer is necessary regardless of CT results, it should not be postponed. Similarly, only emergency procedures or interventions that prevent deterioration during transport should be performed. Necessary interventions include endotracheal intubation, tube thoracostomy, and stabilization of pelvic fractures; non-emergency procedures like laceration repair, unless to prevent exsanguination, should not delay transfer. For hemodynamically unstable patients, immediate transfer is critical.

Transfusion can begin at the initial facility or be performed during transport by sending units of blood with the emergency transport team.

The decision to transfer an unstable patient should be a collaborative effort between the transferring and receiving physicians. Clear communication is essential: sharing vital information enables the receiving clinicians to prepare necessary resources, while failing to do so can hinder timely care. Information must be communicated both verbally and in writing (through the patient record), including the patient's identification, pertinent medical history, prehospital trajectory, and emergency department assessment and treatment (including any procedures done and images taken). Employing a transfer checklist can prevent the oversight of critical information.

Secondary Evaluation and Management

The definitive management of hemodynamically unstable trauma patients should not be postponed for a detailed secondary evaluation. These patients are immediately taken to the operating room, angiography suite, or transferred to a major trauma center.

Upon completing the primary survey, a meticulous head-to-toe secondary assessment is conducted on all trauma patients deemed stable. This secondary survey encompasses a comprehensive history, a thorough yet swift physical examination, and specific diagnostic tests, which are vital in preventing overlooked injuries.

Analgesia and Sedation

Patients suffering from injuries experience pain. It is crucial not to overlook their need for proper analgesia and sedation when necessary. Short-acting agents like fentanyl and midazolam are often favored to minimize adverse hemodynamic effects; however, they necessitate more regular monitoring and administration. Local and regional anesthesia, such as single injection nerve blocks, provide a more direct and focused method of managing pain.

Victims of Crime

The primary responsibility of clinicians treating trauma patients is the clinical evaluation and treatment of injuries. Caretakers should, when possible, preserve potential evidence if the trauma could be related to a crime. This can include actions such as placing removed clothing into paper bags, not cutting through holes made by penetrating injuries in clothing, and meticulously documenting injuries, all of which may be crucial.

Common Pitfalls

The outlined systematic evaluation of trauma patients is intended to assist clinicians in identifying life-threatening issues and reducing the likelihood of overlooking injuries. Clinically significant injuries are defined as those that increase mortality risk, necessitate further procedures, alter treatment plans, or cause considerable pain, complications, or lasting disability.

Esophageal intubations — Some potential pitfalls in trauma management and strategies to avoid them include esophageal intubations, which occur in 0.5 to 6 percent of prehospital intubations due to airway difficulty or displacement during transport.

Hemorrhagic shock — Up to 30 percent of circulating blood volume can be lost before clinical signs of shock begin. If there is only a temporary response to fluid boluses, it likely indicates that the patient is experiencing continuous hemorrhage and remains in a state of shock. It is crucial to maintain a high level of suspicion and conduct a thorough search for the source of the bleeding.

Cardiac tamponade — When evaluating a trauma patient, elevated jugular venous pressure (JVP) may indicate pericardial tamponade. However, it's important to note that hypovolemic patients with tamponade might not exhibit elevated JVP. Therefore, it is crucial to conduct the FAST exam promptly during the circulatory assessment of an unstable patient, starting with an examination of the heart.

Thoracoabdominal injury — It is prudent to consider that a penetrating wound to the thorax or abdomen may affect both areas until it is confirmed otherwise.

Penetrating bowel injury — During initial resuscitation, low velocity penetrating wounds, such as stab wounds, may be overlooked by ultrasound due to minimal intraperitoneal blood, and by CT scans because of insufficient tissue damage. In cases of stab wounds, a high index of clinical suspicion might necessitate further assessment through laparoscopy, laparotomy, or diagnostic peritoneal lavage, even if initial imaging is negative. Alternatively, for abdominal stab wounds and certain extraperitoneal gunshot injuries, a trauma surgeon might consider serial patient observations over a period of 12 to 24 hours.

Gunshot wounds, which are typically high velocity, often require therapeutic laparotomy and should be differentiated from stab wounds. These high velocity injuries carry significantly higher morbidity and mortality rates than low velocity injuries.

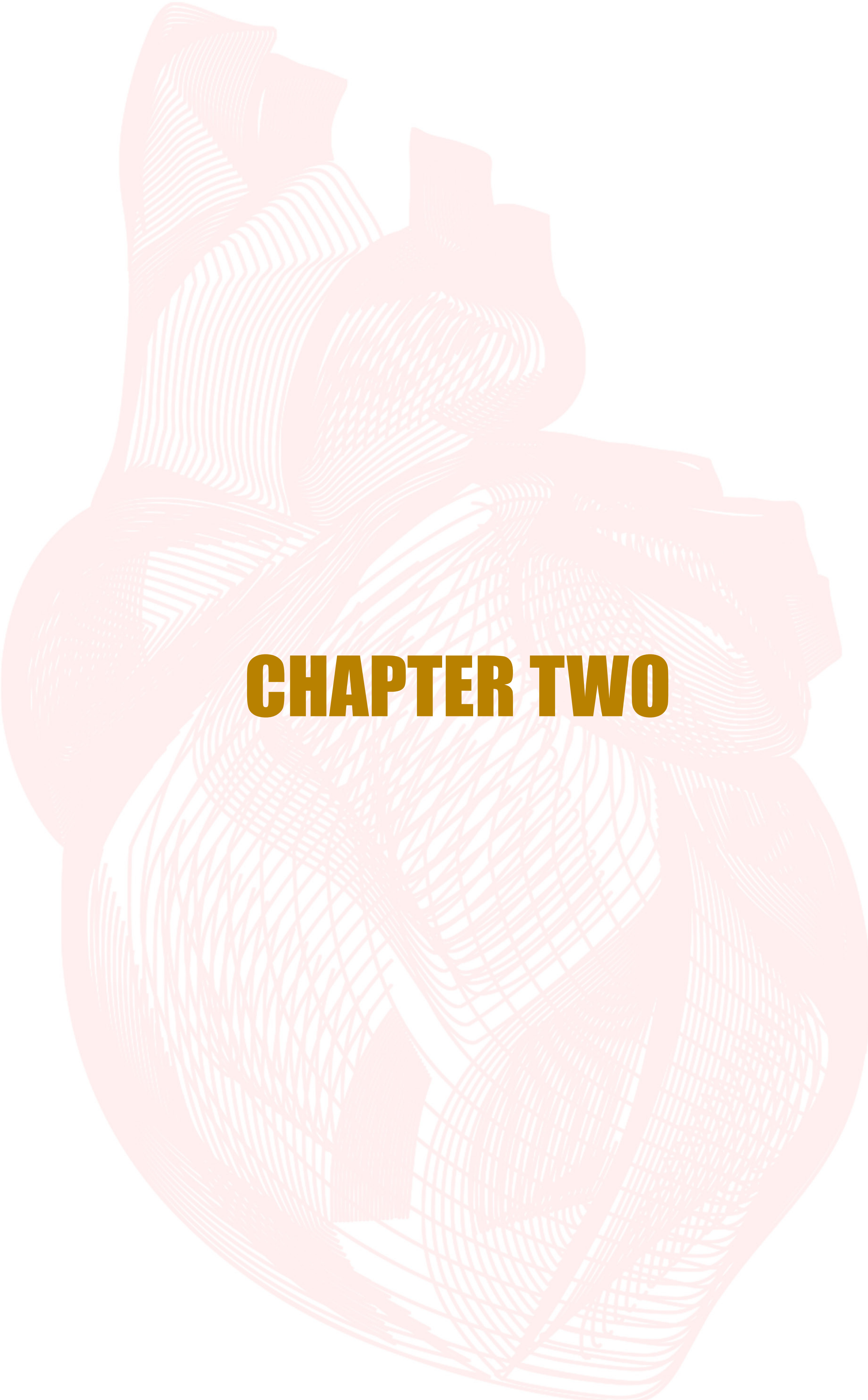
Open book pelvic fractures — Repeated manipulation of an unstable pelvis should be avoided as it can worsen bleeding. When open or unstable pelvic fractures are suspected, they should be immediately stabilized with a pelvic binder, or a sheet if a binder is not at hand. Computed tomography (CT) imaging should be performed if the patient is hemodynamically stable. In cases of instability, the patient may require surgery or angiography.

Ocular injuries — Periorbital swelling and ecchymosis do not prevent the performance of an ocular examination. Patients presenting with these symptoms are at an increased risk of sustaining ocular injuries. Moreover, conditions like globe rupture or retro-orbital hematoma require rapid diagnosis to optimize the chances of preserving vision.

Elder patients — It is prudent to consider that older trauma patients may have sustained significant injuries, even if they present with a seemingly stable condition. The complexity of elder trauma lies in the fact that their physiological responses and medical treatments can conceal or intensify the extent of their injuries.

Common cognitive errors — There are several cognitive errors that frequently occur during the initial treatment of injured patients, especially those who may not appear ill at first. These include:

- Premature diagnosis – The hemodynamic status of trauma patients can change rapidly, and initial diagnostic results are often not definitive. It's important to avoid early assumptions about the extent of patients' injuries and their stability.
- Overreliance on early negative results – No diagnostic test is infallible, and initial tests may not capture the full scope of a patient's injuries or may miss them entirely. Continually reassess the patient. This reassessment could involve repeated eFAST exams if there has been a change in the patient's condition.
- Misinterpreting abnormal findings as benign – Trauma patients, particularly young and healthy individuals, may not show immediate signs of serious injury. Treat any abnormal findings as potential indicators of trauma.
- Distractions – Visible and severe injuries, the performance of critical procedures, and other elements of trauma care can divert clinicians' attention, leading to overlooked injuries or changes in the patient's condition that are less obvious but equally serious.



CHAPTER TWO

Airway

Learning Objectives:

At the end of this chapter, the reader will be able to :

- Assess the patient airway .
- Know how to manage the patient airway using basic and advanced airways.
- Recognize the potential for a difficult airway.
- Understand the use of surgical airways in the resuscitation room.

Introduction:

Ensuring the trauma patient's airway is unobstructed and oxygenation is adequate is vital for effective resuscitation and is a primary intervention. Overlooking an airway blockage can lead to hypoxemia and possible cardiopulmonary arrest. Airway management basics are often neglected, leading to preventable deaths. Once the airway is patent, securing it is crucial for sustained oxygenation and reducing aspiration risks. Spinal cord damage must be avoided if the cervical spine is at risk. This section will detail assessing, clearing, and maintaining the airway, and providing oxygenation without harming the spinal cord.

Standby preparation and transfer

Before the patient's arrival, the airway team should verify all equipment is functional. Upon hospital entry, an immediate airway evaluation is part of the initial 5-second check. Any signs of compromise require swift action to clear and secure the airway using basic methods while also immobilizing the head and neck. This can involve various devices or manual techniques based on the established protocol, ensuring the spine stays immobile and the airway remains open during any movements to the resuscitation area.

Primary survey

The simplest airway check involves asking the patient a question; a clear response indicates an unblocked airway, sufficient breath, and adequate cerebral perfusion. A non-response or unclear answer prompts a more thorough examination using the look, listen, and feel method—checking for chest and abdominal movement, listening for unusual breathing sounds, and feeling for airflow from the mouth and nose.

Figure 2.1 Breathing AssessmentAn Obstructed Airway:

For a patient with a patent airway, breathing is expected to be soundless, without atypical sounds, indicating adequate airflow through the mouth and nose. Normal respiratory movements are observable, despite potentially increased breath rates from low oxygen or elevated carbon dioxide levels. Administering oxygen with a mask and monitoring with pulse oximetry is advisable. However, a patent airway doesn't ensure sufficient ventilation, particularly with potential thoracic injuries present, necessitating possible ventilation support.

Airway blockages, varying from partial to full, can occur from the nasal and oral regions to the bronchial passages, due to factors like reduced muscle control, obstructions, or spasms. In partial blockages, the patient may exhibit rapid breathing, distress, and use of additional muscles for breathing. Observations may include stridor or wheezing, indicating the obstruction location, and decreased air flow. However for complete blockages, expect the absence of breathing sounds and potentially abnormal thoracic and abdominal movements during inhalation.

Without prompt correction of airway blockages and restoration of oxygenation and breathing, oxygen deprivation can damage the brain and other critical organs, leading to potential cardiac arrest.

Basic techniques for opening the airway:

- While employing techniques to clear the airway, it's recommended to administer high-concentration oxygen using a mask, given the infrequency of complete obstructions.
- Basic airway clearance methods involve removing any visible obstructions. Use a suction catheter for minor blood and secretions, and a Yankauer for larger volumes.

Figure 2.2: Suctioning

For solid particles, Magill forceps are appropriate. Chin lifts and jaw thrusts are initial steps to alleviate airway obstruction, monitored for effectiveness by observation, listening, and feeling, while keeping the neck stable.

Figure 2.3: Magill forceps

Adjuncts to basic airway techniques:

Supplementary airway tools like the Oropharyngeal airways, shaped plastic tubes, help prevent obstructions from the tongue or palate, while the oropharyngeal is airway is useful as an adjunct to intubation as we will learn in advanced airway techniques, nasopharyngeal airway is less useful in trauma settings. These aids may not fully secure the airway and could require additional jaw thrusts. After placement, airway checks should be redone. An oropharyngeal airway suggests the airway isn't fully protected, increasing the risk of aspiration; thus, advanced airway management will be necessary.

Table 2.1: Indications and Contraindications of Basic Airway Adjuncts

	Oropharyngeal Airway	Nasopharyngeal Airway
Indications	Temporary airway adjunct Partial or complete airway obstruction Mostly used as an adjunct to advanced airway and while ambu-bagging	Temporary airway adjunct for Partial or complete airway obstruction when oral access is not possible e.g. locked jaw "trismus" Rarely used in trauma
Procedure	To be used only in semiconscious patient or after initial sedation (not to be used in a fully conscious patient due to gag reflex and risk of aspiration	
Complications	Vomiting , bleeding	Vomiting , Bleeding
Pitfalls	Displacement of the tongue posteriorly causing further obstruction if not inserted properly	Misplacement and failure to insert in the proper nasopharyngeal space.

Figure 2.4 Measuring the correct size of OPA & NPA

Cervical spine immobilization

Cervical spine protection is paramount during airway procedures. If the patient lacks spinal immobilization, apply MILS immediately. After airway evaluation and interventions, replace MILS with appropriate stabilization devices. For airway procedures like intubation, temporarily remove any immobilization, applying MILS throughout the process to avoid injury.

Figure 2.5: Manual in-line stabilisation (MILS)

Table 2.2: MILS

Indications:	Actual or potential risk of injury to the cervical vertebrae or spinal cord.
Procedure:	Stabilisation of the head and neck by a team member.
Complications:	Difficulties with airway management.
Common pitfalls:	Exacerbation of injury due to use of excessive force.

Adequacy of oxygenation:

Oxygen delivery after device insertion involves rechecking airway patency. Assuming normal breathing, oxygenate with a high-flow mask. If breathing remains insufficient, mechanical ventilation may be required.

Bag-mask ventilation:

The bag-mask ventilation device is a primary and widely utilized tool in respiratory management, particularly for patients who are incapable of adequate breathing. The mask is designed to cover both the mouth and nose. As the bag is manually compressed, it delivers air into the lungs and releases expired gases. The effectiveness of this device hinges on the operator's ability to maintain an airtight seal and ensure proper airway alignment, which can be challenging. Inadequate technique may lead to under-ventilation or inadvertent inflation of the stomach, increasing the likelihood of regurgitation and aspiration. Advanced airway management, including devices like supraglottic airways, tracheal tubes, or surgical airways, is often necessary. Maintaining cervical spine stability is essential, particularly if there is a risk of spinal injury.

Pulse oximetry:

Pulse oximetry plays a vital role in assessing oxygenation in trauma care. It measures the oxygen saturation level (SpO2) and heart rate, displaying both numerical values and waveform data. However, the device's reliability is influenced by several factors. It can provide inaccurate readings in cases of vasoconstriction, specific hemoglobin anomalies, low hemoglobin levels, or when the patient is moving excessively.

Additionally, the relationship between saturation percentage and partial oxygen pressure is not linear, meaning a small drop in saturation can indicate a significant decrease in oxygen content in the blood. This tool is essential but must be used with an understanding of its limitations and in conjunction with other clinical assessments.

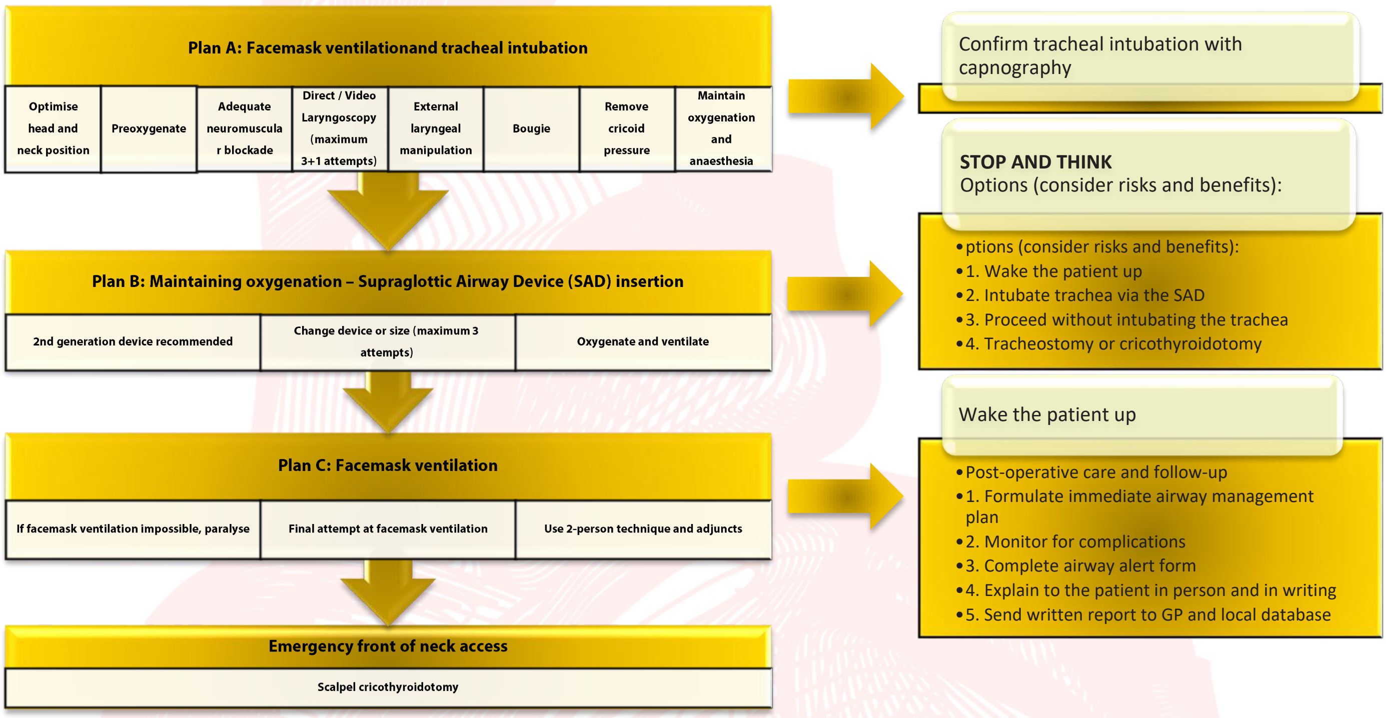
Advanced airway techniques:

In instances where basic airway management techniques are inadequate, advanced airway management becomes crucial. This need arises in various situations, such as severe facial injuries, significantly reduced consciousness where an oropharyngeal airway is tolerated, airway threats from swelling in cases of burns and inhalational injuries, cervical fractures, respiratory compromise due to chest trauma, or specific ventilation requirements in traumatic brain injuries.

Utilizing advanced airway techniques typically involves administering anesthetic drugs, which elevates the risk of potentially fatal complications. Therefore, it is imperative that only a team of clinicians experienced in emergency advanced airway management perform these procedures.

To reduce the risk of complications, implementing structured protocols and approaches is recommended. The Difficult Airway Society (DAS) guidelines, widely adopted across Europe, provide a flow diagram to guide clinicians through various airway challenges.

Algorithm 2.1: Difficult Airway Society guidelines for management of unanticipated difficult intubation (2015).



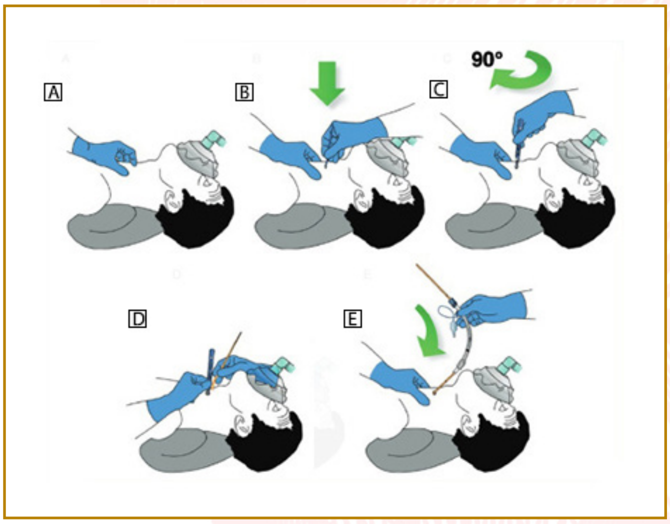


Figure 2.7 Needle cricothyrotomy

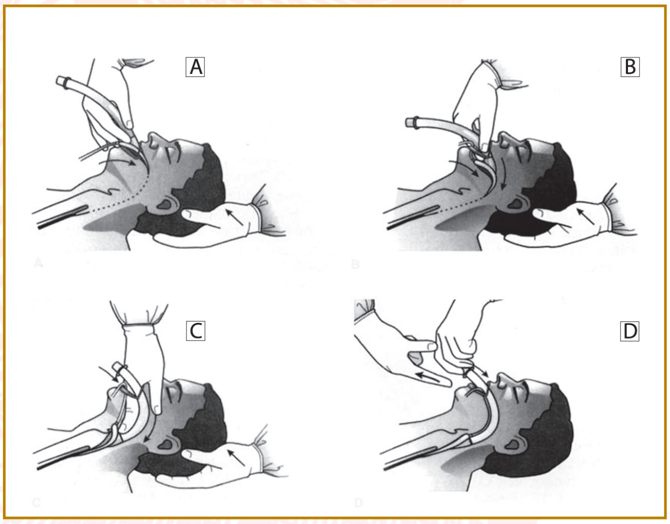


Figure 2.6 LMA Insertion

Another approach is the Vortex method, which offers a conceptual framework to be used in conjunction with any difficult airway algorithm. This approach visualizes airway management as a funnel, with the upper edge representing a safe zone where the patient can oxygenate and ventilate independently. Once anesthesia is induced, the patient moves out of this safe zone, and a series of structured attempts at intubation, supraglottic airway insertion, or bag-mask ventilation are made to return to safe oxygenation levels. Each technique is given a limited number of attempts, and failure to restore oxygenation escalates the situation towards a critical **cannot intubate, cannot oxygenate** (CICO) scenario, necessitating an emergency surgical airway.

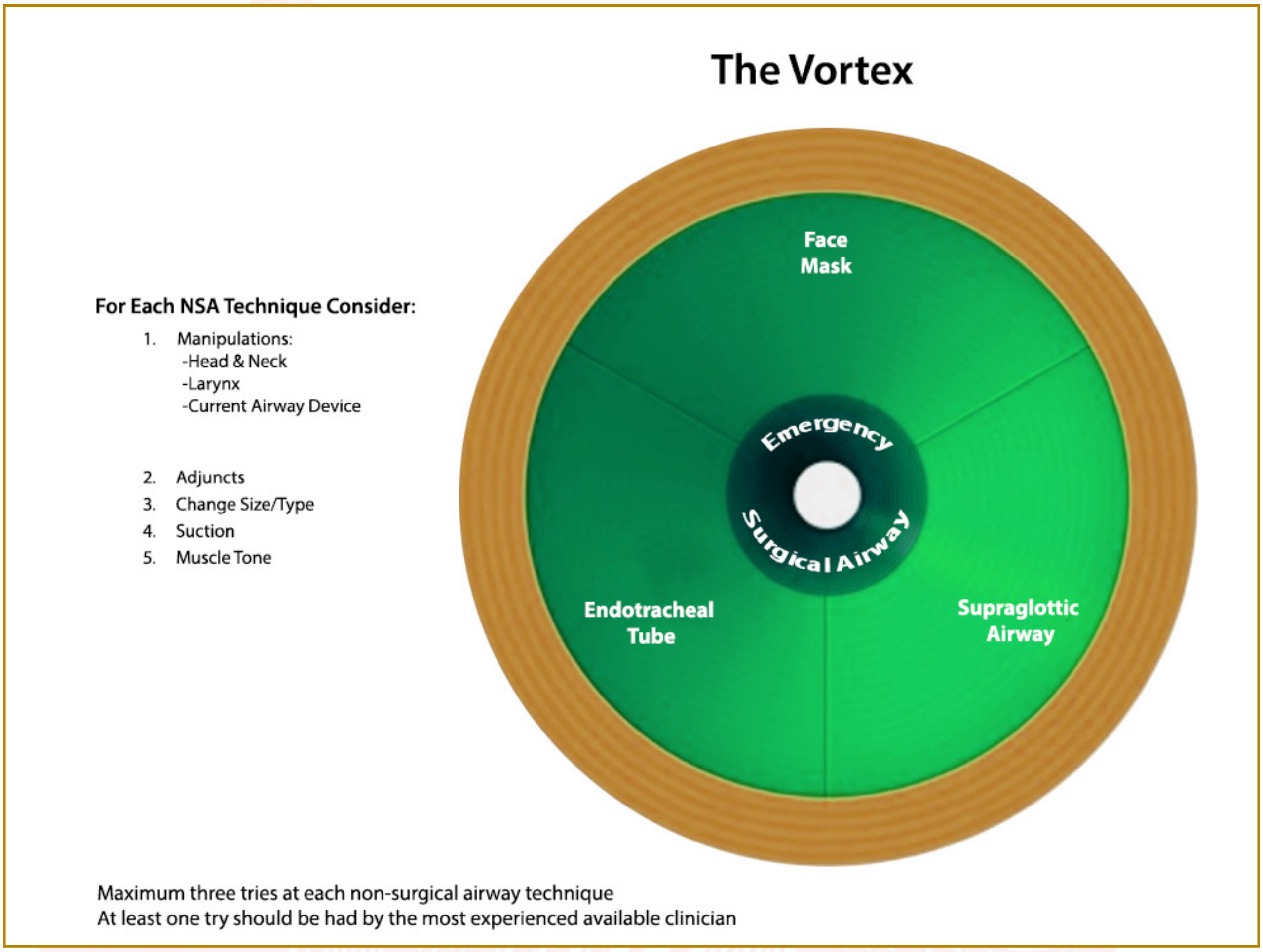


Figure 2.8: The VORTEX- approach, Nicholas Chrimes and Peter Fritz

Advanced airway management practices vary significantly worldwide, influenced by factors such as available equipment, medical protocols, and the structure of pre-hospital and hospital emergency care. In some regions, physician-led pre-hospital systems may opt for drug-assisted tracheal intubation early on, while in others, such interventions are reserved for the emergency department under the guidance of an anesthetist.

Algorithm 2.2: Saudi Trauma Course - Airway Algorithm

Saudi Trauma Course
Airway Algorithm

When approaching a trauma patient that requires an advanced airway, it's essential to plan and prepare, as every second counts once the patient is sedated and paralyzed.
There are multiple techniques and algorithms for different clinical situations, and the following might be the most suited for trauma cases. The sequence usually follows:

Prepare the environment > Prepare yourself > Prepare your team
Make sure you have an adequate place to maneuver at the head of the patient, and the monitor is visible to you and the team. Each team member should be in the proper place; your airway assistant should be close to you, and the medication nurse should have access to an IV line.

Plan and share it with your team
A trauma advanced airway is a difficult airway because the patient is not fasting, has a potential full stomach, and the risk of aspiration is very high. Therefore, attempting intubation must be done by the most experienced physician in the team, and no trials should be attempted by less experienced personnel.
The default plan for trauma intubation is Rapid Sequence Intubation (RSI), meaning no gap time for preoxygenation after the paralyzing agent is administered.

Plan 1: Simple Laryngoscopy ± Bougie	vPlan 2: Video Laryngoscopy ± Try changing the blade	Plan 3: Call for help, LMA	Plan 4: CICO (Surgical Airway)

Preparation of Instruments (MALE4S)

Mask (Ambubag)	Airway Adjuncts (Oral Airway, LMA Airway)	Laryngoscope (with different size blades)	ETT (with different size blades)	4S (Stylet, Suction, Syringe, Stethoscope)

Position of the Patient's Head
The cart should be adjusted so that the head is positioned in line with the physician while maintaining inline stabilization.

Pre-Oxygenate
Ideally, this is the only window for oxygenation, so ensure the patient is oxygenated. It is recommended to utilize both a nasal cannula and bag-mask ventilation if two oxygen sources are available (Apneic Oxygenation).

Pre-Treat
Some medication can be used to blunt the hypertensive reflex from laryngoscopy (can decide whether to include details about specific pre-medications).

Paralyze
Administer the induction agent, followed immediately by paralyzing medications (can either list medications or leave it simple).

Post-Intubation
Confirm placement, inflate the cuff, secure the tube, and connect to mechanical ventilation.

Supraglottic airway devices:

In advanced airway management, second-generation supraglottic airway devices (SADs) are the preferred choice due to better aspiration protection than their predecessors. The specific device used depends on what's available, with examples including the laryngeal mask airway (LMA), i-gel, and laryngeal tube (LT), along with their variants. These devices facilitate gas exchange by directing airflow through them into the hypopharynx, and then, if unobstructed, into the trachea and lower airways. They achieve a secure seal around the hypopharynx using a cuff, which can be either air or gel-filled, to prevent air leakage. One major advantage of these devices is their relatively straightforward insertion process, which typically doesn't require anesthetic drugs. Therefore, it's important for all members of a trauma team to be proficient in using a supraglottic airway device. In every patient where an airway is secured using these devices, it's a standard practice to insert a gastric tube.

Table 2.3: SGA indications and complications

Indications:	Need for advanced airway and limited skills available, failed tracheal intubation, and failed ventilation with bag-mask.
Procedure:	Insertion of an SGA device.
Complications:	Leak, gastric insufflation, trauma to the airway.
Common pitfalls:	Unrecognized inadequate ventilation when using the device, patient's level of consciousness prevents insertion.

Tracheal intubation:

Tracheal intubation is a more complex procedure, involving inserting a tube through the mouth directly into the trachea, usually under direct vision with a laryngoscope. The tube's distal end is equipped with a cuff that's inflated to create a gas-tight seal, enabling positive pressure ventilation and preventing aspiration.

Pre-oxygenation and apneic oxygenation techniques are advised in trauma patients to maintain oxygenation during intubation. Tracheal intubation presents several challenges, especially in patients with cervical spine immobilization, as this restricts mouth opening. It requires skilled practitioners, and in major trauma cases, Rapid Sequence Induction (RSI) of general anesthesia is the recommended method. Care must be taken with drug dosing in shock patients due to the risk of cardiovascular collapse. Controlled ventilation can affect venous return to the heart, another factor to consider during anesthesia in major trauma patients. Using tracheal intubation checklists, which include preparation steps, required equipment, choice of induction drugs, and clear role definitions within the trauma team, is crucial for safe and effective procedure. These checklists also detail backup plans and are used for all major trauma patients, except in cases of moribund patients or those in cardiorespiratory arrest.

A rapid assessment to predict difficulty in intubation is vital, and if difficulty is anticipated, intubation should be performed only by those experienced in managing difficult airways and with the appropriate equipment, unless there's an immediate life-threatening situation.

Recognising a potentially difficult airway

Identifying a challenging airway is key and can be categorized into two primary scenarios:

1. Difficulties in oxygenating the patient with standard mask and adjuncts, which may stem from:

- Extensive facial trauma, such as unstable fractures or deep cuts
- Restrictions due to cervical immobilization
- Blockage in the upper airway, like blood or vomit
- Atypical anatomical structures, including unusual facial features, enlarged tongue.
- Extreme body conditions, like severe underweight or obesity
- Dense facial hair

2. Complications in performing laryngoscopy, hindering clear visualization of the larynx for tube placement, potentially caused by: a. Pre-existing anatomical variances, often indicated in medical alerts:

  - Limited neck movement, for instance in rheumatoid arthritis
  - Large upper front teeth
  - Small lower jaw
  - Enlarged tongue
  - Scarring from previous surgeries

3. Trauma Related factors:

  - Swelling from burns
  - Severe facial injuries with bleeding
  - Neck injuries
  - Limited mouth opening due to cervical collars

After placing an advanced airway, initiate oxygenation and ventilation with a self-inflating bag, high-flow oxygen, and a reservoir. Monitor oxygenation using a pulse oximeter, confirm ventilation with capnometry, and validate with arterial blood gas analysis.

Algorithm 2.3: Emergency Induction Checklist, European Trauma Course

EMERGENCY INDUCTION CHECKLIST

PREPARE PATIENT

- ➢ Preoxygenation?
- ☐ Applying 100% O_2
- ☐ Apnoic oxygenation
- ➢ Is the patient's position optimal?
- ☐ Consider sitting up
- ➢ Vascular access?
- ☐ Intravenous cannulation
- ☐ Intraosseous cannulation
- ➢ How will anaesthesia be maintained after induction?

PREPARE EQUIPMENT

- ➢ What monitoring is applied?
- ☐ Capnography
- ☐ SPO_2 probe
- ☐ ECG
- ☐ Blood pressure
- ➢ What equipment is checked and available?
- ☐ Self-inflating bag
- ☐ Working suction
- ☐ Two tracheal tubes
- ☐ Two laryngoscopes
- ☐ Bougie
- ☐ Supraglottic airway device
- ➢ Do you have all the drugs required?
- ☐ Induction agent
- ☐ Muscle relaxant
- ☐ Vasopressor

PREPARE TEAM

- ➢ Allocate roles:
- ☐ Team leader
- ☐ First intubator
- ☐ Second intubator
- ☐ Intubator's assistant
- ☐ Drugs
- ☐ MILS (if indicated)
- ☐ Rescue airway
- ➢ How do we contact further help if required?

PREPARE FOR DIFFICULTY

- ➢ If the airway is difficult, could we wake the patient up?
- ➢ What is the plan for a difficult intubation?
- ☐ Plan A: RSI
- ☐ Plan B: BMV
- ☐ Plan C: Supraglottic airway
- ☐ Plan D: "Front of neck access" – FONA
- ➢ Where is the relevant equipment, including alternative airway?
- ☐ DO NOT START UNTIL AVAILABLE
- ➢ Are any specific complications anticipated?

Surgical airway

A surgical airway becomes necessary when all other ventilation techniques have been unsuccessful and the patient's oxygen levels continue to drop, typically due to severe airway blockage, such as swelling from burns or laryngeal trauma. Prior to performing a surgical airway, it's advised to pause briefly for a team discussion to evaluate options. Clear communication and swift action are critical when deciding to proceed with a surgical airway. The specific technique depends on the team's expertise. Training in front-of-neck access and a scalpel-based surgical airway technique is essential for all team members, involving inserting a tracheal tube through the cricothyroid membrane. For those not trained in surgical airway techniques, a needle cricothyroidotomy, which involves inserting a cannula into the trachea, may be used, though it carries its own risks. Both methods are interim solutions to maintain oxygenation and ventilation while awaiting more specialized airway management assistance.

Team issues in airway management

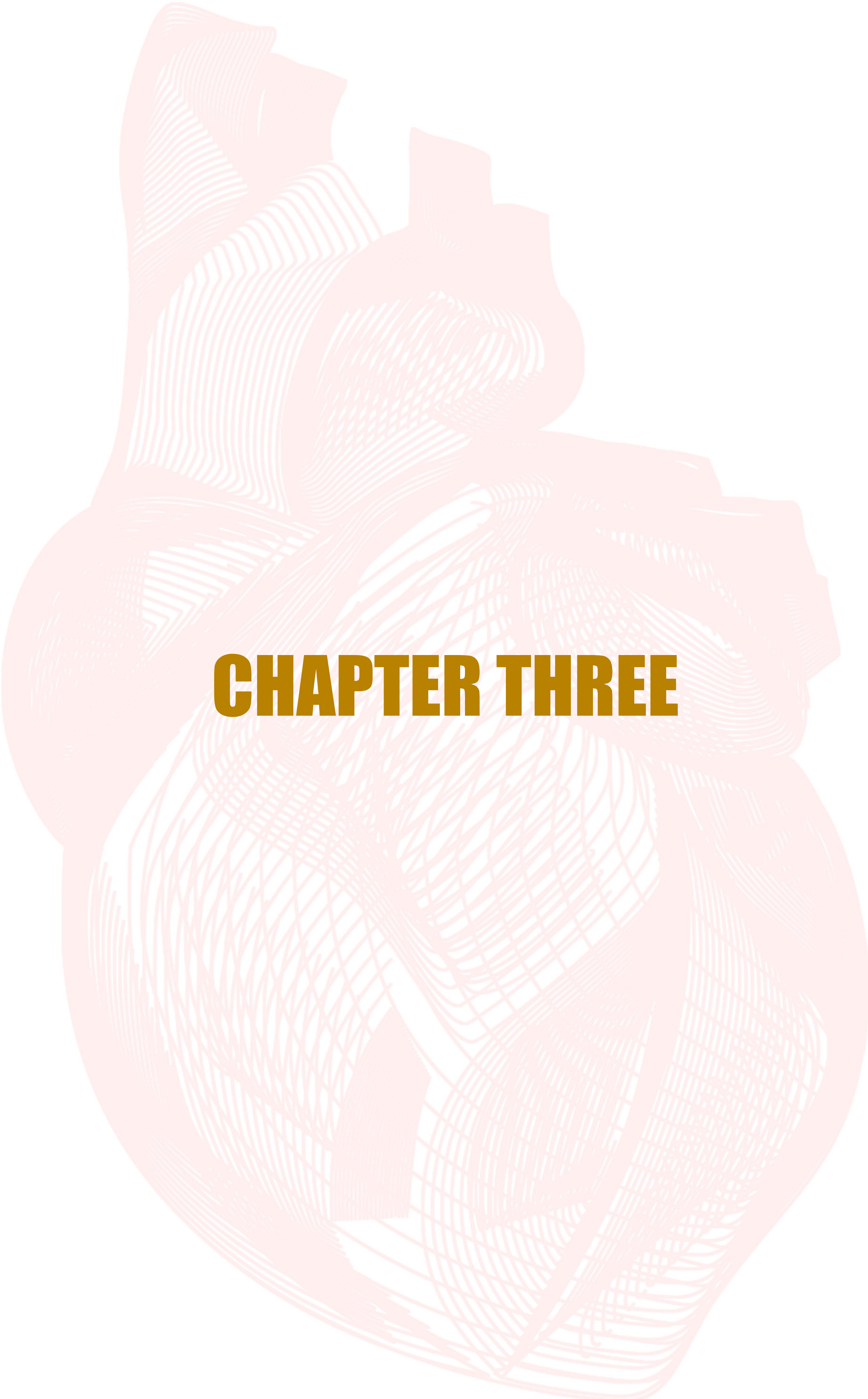
In trauma care, airway management is a collaborative effort within the team. While a specific medical member is responsible for the airway, the complexity of the task often necessitates involvement from others. For example, effective bag-mask ventilation typically requires a two-person technique, and even more personnel might be needed if a cervical collar is involved and manual in-line stabilization (MILS) is necessary. The team leader plays a pivotal role in reallocating tasks based on the evolving needs of airway management, especially in scenarios requiring tracheal intubation. In such cases, tasks are distributed among team members according to their skills—some apply MILS, others handle the removal of collars and stabilizing devices, and another administers anesthetic drugs, and all tasks are done simultaneously.

Figure 2.9: Manual in-line stabilization (MILS) and cervical collar

Coordination and communication are crucial, with the intubation specialist temporarily guiding the procedure and the team leader maintaining an overall perspective. Additionally, a clear plan B for failed intubation or ventilation must be pre-established, identifying team roles for alternative measures like supraglottic airway devices or surgical airway techniques. After securing the airway, team members can revert to their regular duties.

Mechanical ventilation

In conjunction with tracheal tubes, mechanical ventilators are employed to ensure appropriate ventilation levels. Their usage frees airway personnel to support other tasks. Only those trained and competent should operate mechanical ventilators, with settings tailored to each patient's specific needs and frequently reassessed through arterial blood gas analysis.



CHAPTER THREE

Breathing problems and Thoracic trauma

Learning Objectives:

At the end of this chapter, the reader will be able to :

- Assess the thoracic injuries .
- Know how to manage the immediate and potential life threatening thoracic injuries.
- Select and interpret the thoracic injuries related diagnostic procedures and investigations..
- Know how to demonstrate thoracic injuries related interventions as chest tube insertion and needle decompression.

Introduction:

Thoracic trauma accounts for about 25% of all injury-related deaths and contributes to an additional 50%, typically due to hypoxia and/or hypovolemia. The mortality rate for isolated penetrating trauma to the lung and pleura is low (less than 1%), but it increases 20-fold if the heart is involved. In Europe, the most common injuries are to the chest wall, followed by the pulmonary parenchyma and pleural space. The vast majority (around 85%) of these injuries can be successfully treated without surgical intervention. However, it is important to recognize that these patients often have other injuries, particularly to the head, which contributes to the high overall mortality rate.

Assessment and management

This follows the well-defined protocol for all trauma victims used throughout this course, remembering that the primary survey and resuscitation are simultaneous events.

Primary survey and resuscitation

As outlined in Chapter 1, the goal is to identify and address immediately life-threatening conditions. The medical team needs to manage six critical conditions that can result from thoracic trauma:

- Tension pneumothorax
- Open chest wound / open pneumothorax
- Massive hemothorax
- Flail chest
- cardiac tamponade
- airway obstruction/disruption

Chest Ultrasound (CUS)

Ultrasound is more accurate than a chest X-ray in detecting a pneumothorax. This also applies to the detection of a hemothorax or cardiac tamponade. The eFAST (Extended Focused Assessment with Sonography for Trauma) is especially useful in guiding resuscitation efforts for severely compromised patients. Consequently, eFAST has become an integral part of the primary survey in many advanced trauma care systems, particularly when computed tomography is not immediately available.

Tension pneumothorax

A pneumothorax arises when air leaks into the pleural space through a breach in the pleural cavity. This can occur spontaneously or result from chest wall trauma. Tension pneumothorax occurs when the breach functions as a 'one-way valve,' permitting more air to enter on inspiration than is released on expiration. As air builds up, the pressure within the pleural cavity escalates, resulting in:

- Collapse of the lung
- Depression of the diaphragm
- Distension of the hemithorax
- Mediastinal shift away from the affected side

The pulmonary effects lead to hypoxemia, and the increased thoracic cavity pressure decreases venous return and cardiac filling, causing reduced cardiac output and hypotension. These conditions are exacerbated by any existing hypovolemia. Notably, these cardiovascular symptoms are akin to those seen in cardiac tamponade. The body's initial compensatory response is to stimulate respiration, causing tachypnea and heightened respiratory effort. To preserve cardiac output and organ perfusion, there is a surge in catecholamine release and adrenergic activity, which induces tachycardia and vasoconstriction.

If a tension pneumothorax is not promptly addressed, the body's compensatory mechanisms will become overwhelmed, leading to diminished respiratory effort, hypotension, respiratory arrest, and eventually, cardiac arrest. Ventilated patients exhibit these symptoms quickly as the ventilator's positive pressure pushes air into the pleural space. Conversely, patients who breathe spontaneously show symptoms more slowly due to the gradual air leak, which they counteract by elevating their respiratory rate and tidal volume. Consequently, the evaluation and treatment of these two patient groups should be distinct.
Diagnosing a tension pneumothorax in a spontaneously breathing trauma patient can be challenging, especially in the early stages, as symptoms can be variable. If the patient is compensating (normal SpO2 and BP) and chest X-rays can be obtained in the resuscitation area without delay, a chest X-ray is appropriate. The absence of specific radiological features will prevent unnecessary interventions. Any patient showing signs of cardiorespiratory compromise requires rapid chest decompression. This can occur suddenly and without warning, so a competent team member should stay with the patient while the X-ray is taken.

Bilateral tension pneumothoraces, although uncommon, can arise. They might be detected through sonography, but should also be suspected in the absence of localizing signs when there is significant

hypoxia, surgical emphysema, cardiovascular collapse, or in a patient on mechanical ventilation, a progressive increase in peak inspiratory pressures.

Immediate chest decompression is required if a tension pneumothorax is confirmed or suspected in a ventilated patient. This will necessitate a lateral thoracostomy followed by the insertion of a chest tube (immediately for a spontaneously breathing patient or after performing airway life-saving procedures for a patient in respiratory arrest).

Bilateral thoracostomies are necessary for cases of bilateral tension pneumothoraces or when the side is in doubt, a situation that can arise in the suddenly decompensating, intubated, and ventilated patient. Needle decompression (needle thoracocentesis) should be considered a last resort if no competent physician and/or equipment is available.

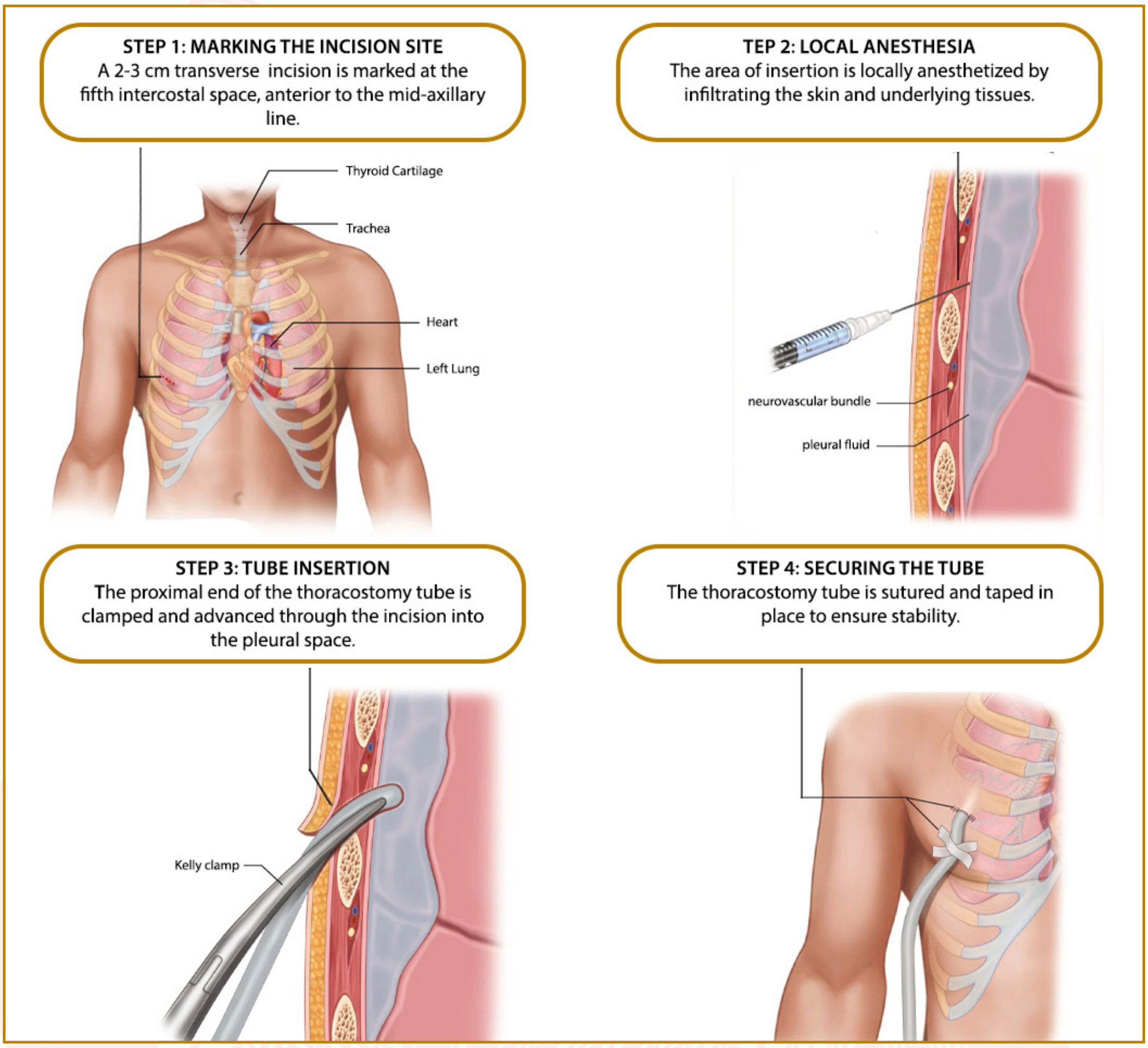


Figure 3.1: Needle decompression (needle thoracocentesis)

Lateral thoracostomy

This involves performing the initial stages of a tube thoracostomy procedure without inserting the chest drain. This technique allows for rapid chest decompression and serves both diagnostic and therapeutic purposes. Repeated finger sweeps can be performed to check for re-accumulation of tension if the patient's condition deteriorates again.

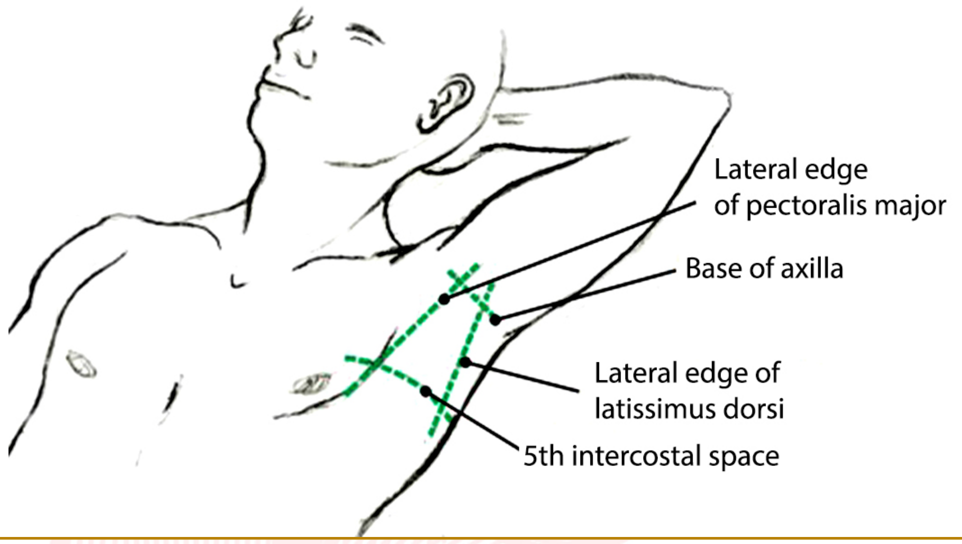


Figure 3.2: Thoracostomy Insertion Site

Open chest wound

In spontaneously breathing patients, any breach in the chest wall invariably results in a pneumothorax. The size of the wound dictates the volume of air that bypasses the lungs and enters the pleural space during inspiration, causing the lung to collapse. In contrast, ventilated patients seldom experience this because the positive pressure in the lungs prevents collapse.

The shape of the wound or an overlying dressing can allow air to enter but not exit, often called a 'sucking chest wound,' which can cause a tension pneumothorax. Immediate treatment requires the removal of any occlusive dressing to let air out. Subsequently, a one-way adhesive chest seal is applied, allowing gas and blood to exit the pleural cavity and preventing air from re-entering. This measure buys time for the placement of a chest drain through another incision and for proper redressing of the wound.

Massive haemothorax

This condition is defined as having more than 1500 ml of blood in the thoracic cavity. It usually results from a laceration of either the intercostal or internal thoracic arteries. Less commonly, it can arise from injury to a mediastinal great vessel (e.g., pulmonary hilum) or spillage into the pleural space from a cardiac laceration. The accumulation of blood in the pleural cavity compresses the lung, impairs ventilation, and causes hypoxia, while also leading to hypovolemia. Patients with ongoing drainage of more than 200 ml/hour will require urgent surgical review to assess the need for thoracotomy. Diagnosis is readily confirmed by plain X-ray or sonography

• Hypovolaemic shock
• Dull to percussion over the affected hemithora
• Decreased breath sounds over the affected hemithorax
• Hypoxia
• Radiologically: In the supine position, a massive haemothorax will result in a unilateral whiteout.
• This will obscure any underlying, co-existing pneumothorax.

Table 3.1: Signs of a massive haemothorax

Immediate management includes providing oxygen, performing tube thoracostomy, establishing IV access, and initiating fluid resuscitation, with early activation of the major hemorrhage protocol. Be aware that inserting a chest drain and releasing retained blood in the thorax may dislodge clots and cause further active hemorrhage. Therefore, it is crucial to ensure adequate venous access for volume resuscitation simultaneously. In addition to aiding diagnosis, chest drainage will improve respiratory function and, where facilities exist, allow for autotransfusion of the blood from the thorax. If the diagnosis is correct, most of these patients will require definitive surgery to control the bleeding.

Flail chest

Flail chest arises when a segment of the thoracic cage loses bony continuity with the chest wall. Typically, this condition stems from trauma that causes multiple rib fractures—specifically, two or more adjacent ribs broken in two or more locations. It may also result from the costochondral separation of a single rib from the thorax.

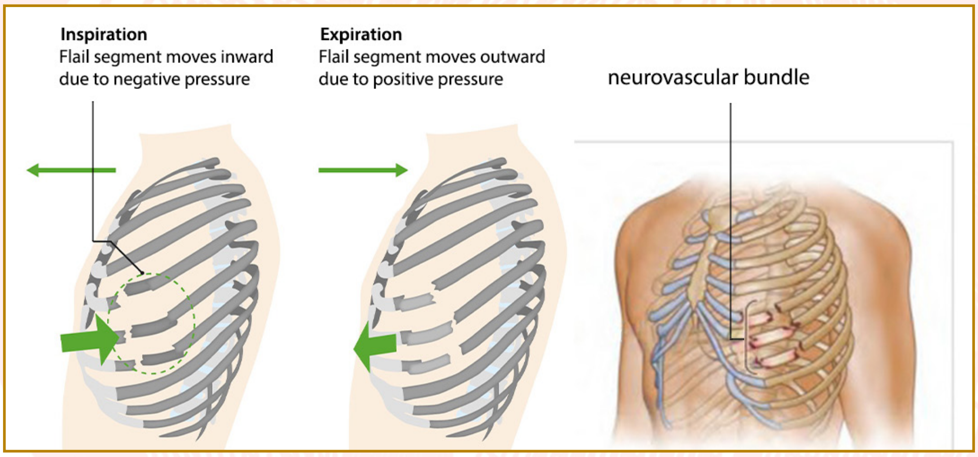


Figure 3.3: Flail Chest

Diagnosing a flail chest can be challenging in young adults, as the flail may not be immediately apparent due to muscle splinting of the fractured ribs. Paradoxical movement will become evident if the patient becomes exhausted, if the flail involves a large segment (approximately six or more ribs), or if it is central (involving the sternum).

As lung contusions are typically present with a flail chest, initial management should include:

- High-flow, warmed, humidified oxygen
- Adequate but cautious fluid resuscitation to prevent overload or pulmonary edema
- Analgesia, usually in the form of intravenous opioids, to allow maximal thoracic cage movement with breathing

During the secondary survey, consider intercostal blocks, epidural analgesia, and infusions of opioids/ketamine or patient-controlled analgesia, depending on the expertise available. Some patients may need tracheal intubation and controlled ventilation. It's important to note that flail chest injuries may coincide with a pneumothorax; thus, insert a chest drain if a pneumothorax is detected or suspected. Arterial blood gases should be frequently monitored in all patients to evaluate respiratory function, and an arterial cannula should be placed by the conclusion of the primary survey. Patients who are intubated should receive a lung-protective ventilation strategy, developed in consultation with critical care specialists.

Cardiac tamponade

Cardiac tamponade must be considered in any individual with a penetrating injury to the chest, neck, or upper abdomen. The central chest area, spanning from the clavicles to the xiphisternum and between the right nipple to the left lateral chest wall, both in front and back, commonly known as "the danger box," is especially perilous. Cardiac tamponade is relatively rare following blunt trauma, especially among patients on anticoagulants or antiplatelet medications.

A penetrating cardiac injury often leads to continuous bleeding into the pericardium, sealed off by a clot at the site of the sac laceration. A minimal amount of blood accumulation in the pericardial sac can impede ventricular filling during diastole, diminishing stroke volume. Initially, cardiac output is maintained through compensatory mechanisms that increase heart rate and perfusion pressure by elevating peripheral vascular resistance.

However, if the obstructive pressure in the pericardial space is not alleviated, cardiac output will progressively decrease, and compensatory mechanisms will become ineffective. This leads to severe hypotension and additional myocardial damage due to decreased coronary perfusion. Without immediate intervention, the patient will succumb to critically reduced cardiac function and perfusion.

The clinical signs of cardiac tamponade are shown in table below, but are observed in only about one-third of trauma patients. In the resuscitation room, diagnosis is best confirmed by sonography. Initial management includes augmenting venous return to maintain cardiac output by elevating the patient's legs (if possible) and rapid IV fluid infusion.

Definitive management requires surgical evacuation of the clot from the pericardial sac and primary repair of the cardiac laceration. The approach depends on the expertise, environment, and equipment available. The most common approach is a median sternotomy, ideally performed in the operating theatre. However, this depends on the clinical urgency and the patient's status. A thoracotomy performed in the Emergency Department can effectively relieve cardiac tamponade. If this expertise is not immediately available, and the patient is dying, pericardiocentesis should be considered only as a last resort.

• Beck's triad
  • Hypotension
  • Raised jugular venous pressure resulting in distended jugular veins
  • Decreased heart sounds (difficult to elicit in the noisy resuscitation room)
• Pulsus paradoxus >10 mmHg fall in SBP during inspiration
• Kussmaul's sign – raised jugular venous pressure on inspiration

Table 3.2: Clinical Signs of cardiac temponade

Emergency Department thoracotomy

An Emergency Department thoracotomy, or resuscitative thoracotomy, may be indicated for three specific patient groups during the primary survey:

1. Patients experiencing cardiac arrest following penetrating trauma, with less than 15 minutes of cardiopulmonary resuscitation (CPR).
2. Patients in cardiac arrest after blunt trauma, with less than 10 minutes of CPR.
3. Patients with refractory hypotension (systolic pressure below 60 mmHg or presence of life signs) despite aggressive fluid resuscitation after penetrating or blunt thoracic injury.

In the absence of an experienced surgeon or if the extent of injuries is uncertain, a bilateral anterior thoracotomy, also known as a clamshell incision, is recommended as it provides access to the entire thoracic cavity. This method allows for direct pressure to control hemorrhage, pericardial opening to relieve tamponade, and the commencement of internal cardiac massage.

For penetrating cardiac injuries, securing with an occluded Foley catheter or suturing may be necessary. Additionally, aortic cross-clamping can help redistribute the limited cardiac output to the brain and heart, while also reducing abdominal bleeding during resuscitation.

Resuscitative thoracotomy results in significant blood splatter, so all team members must wear appropriate personal protective equipment (PPE), including eye protection. The survival rate following Emergency Department thoracotomy is approximately 35% for patients arriving in shock with a penetrating cardiac wound and 15% overall for those with penetrating wounds. However, survival after blunt trauma is poor, with only 1–2% surviving.

Team training for this procedure is beyond the scope of this course, and only those with existing expertise should perform it. Otherwise, the probability of success is negligible and does not outweigh the high risks of damage to thoracic viscera.

Emergency Department thoracotomy allows for:

- Pericardial incision and evacuation of clotted blood causing tamponade
- Local control of cardiac hemorrhage
- Direct control of exsanguinating thoracic hemorrhage
- Open cardiac compression

- Cross-clamping of the descending aorta to maintain cardiac and brain perfusion by stopping blood loss below the diaphragm
- Direct repair of exsanguinating pulmonary hemorrhage
- Cross-clamping of the pulmonary hilum in cases of bronchovenous air embolism

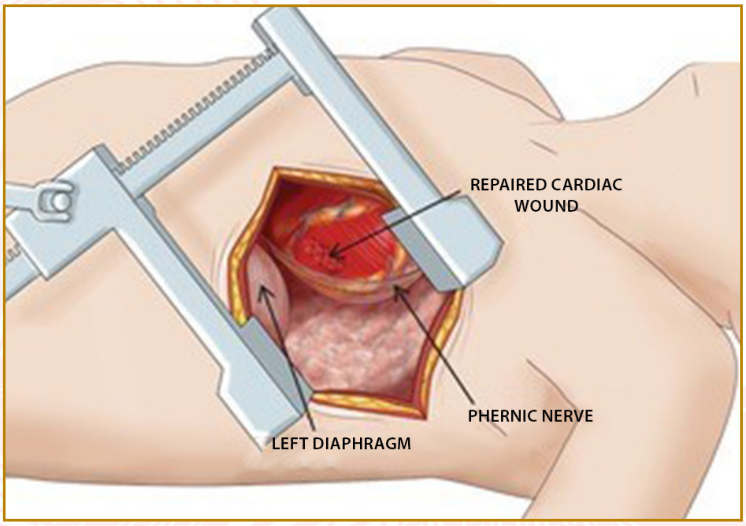
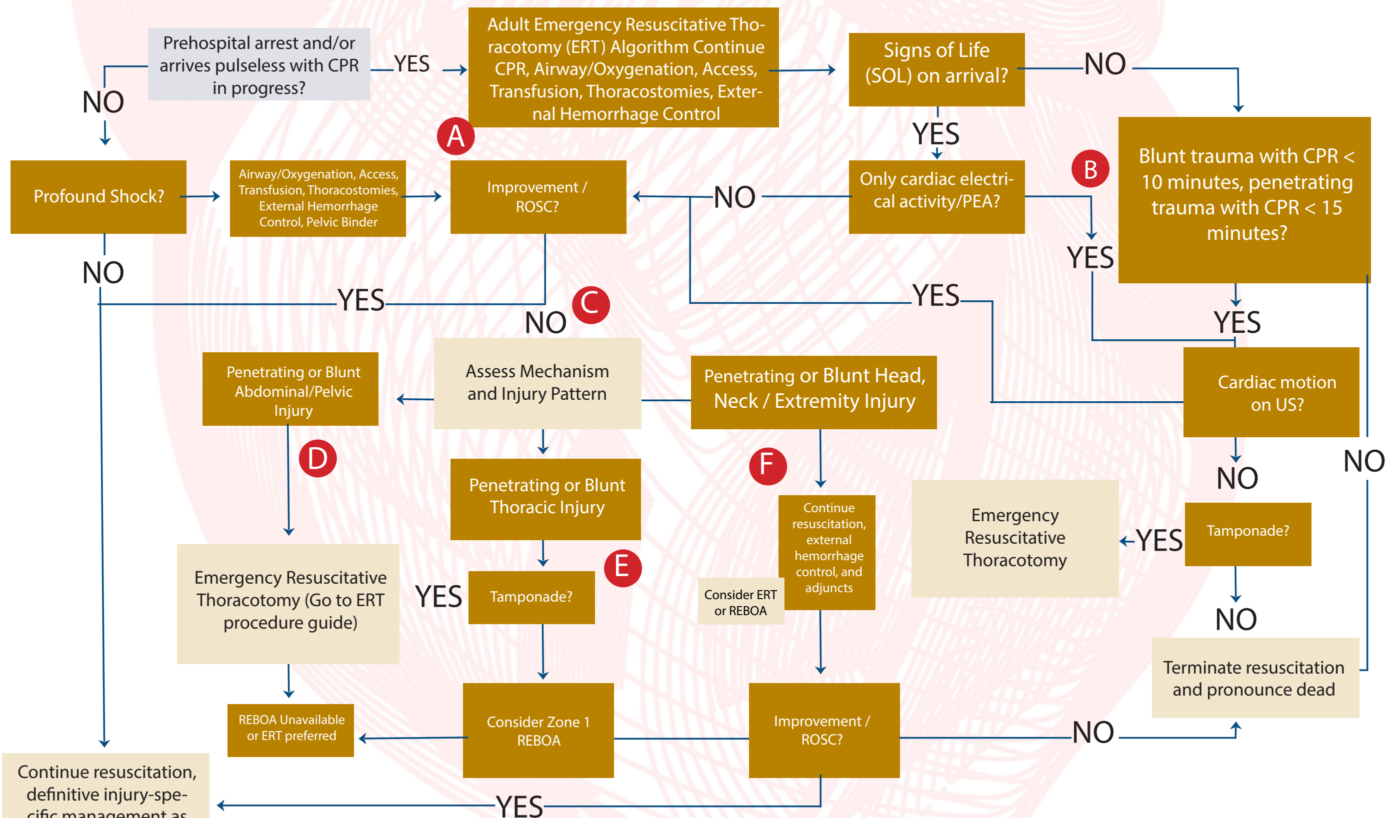


Figure 3.4 Emergency Department thoracotomy



1. Establish airway, continue CPR, obtain vascular access, transfusion, external hemorrhage control, and therapeutic adjuncts.
2. Signs of Life (SOL): Pupillary response, spontaneous ventilation, presence of pulse, measurable blood pressure, extremity movement, electrical cardiac activity.
3. Profound Shock: SBP < 60 mmHg.
4. ROSC: Organized cardiac rhythm with SBP > 70 mmHg.
5. REBOA (Resuscitative Endovascular Balloon Occlusion of the Aorta) may be considered as an alternative to aortic occlusion.

Pericardiocentesis

Pericardiocentesis may be considered under the following uncommon circumstances:

- No team member is competent to perform a thoracotomy.
- The patient is in extremis (i.e., about to die).
- There is a high degree of suspicion of cardiac tamponade, ideally confirmed by sonography.

When performing this procedure, be aware of the following risks:

- Pericardiocentesis can cause damage to organs such as the myocardium, lungs, stomach, bowel, esophagus, spleen, and kidneys, as well as laceration of a coronary artery.
- A formal pericardial exploration will still be required regardless of the pericardiocentesis findings because:
  - Blood clots in the pericardial sac can result in a negative tap even when tamponade is present.
  - False positive aspirations can occur if the coronary arteries or ventricles are penetrated.

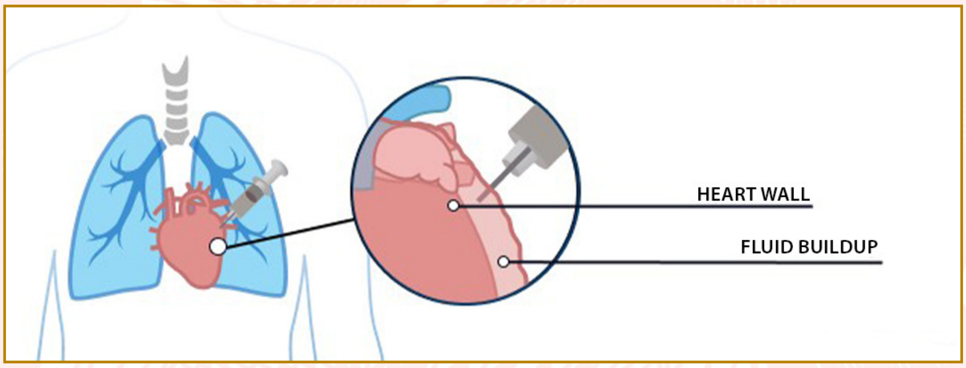


Figure 3.5: Pericardiocentesis

Airway disruption

The majority of patients with significant airway injuries were arrested at the scene due to asphyxia, intrapulmonary hemorrhage, blood aspiration, or air embolism. Nevertheless, survival is feasible if the severed airway, even if substantial, is enclosed by soft tissue. Such injuries may lead to serious surgical emphysema, pneumothorax, pneumomediastinum, hemothorax, pneumopericardium, or pneumoperitoneum.

Diagnosis may be determined by airway personnel while attempting to clear or secure the patient's airway, or in the presence of a significant air leak, such as a large pneumothorax or pneumomediastinum. A high level of suspicion is warranted when associated injuries suggest a high-energy transfer, such as fractures of the scapula, clavicle, or the first to third ribs. Airway endoscopy often provides confirmation, although it can be hindered by free blood or clots in the airway. Since delays in diagnosis can lead to increased risk of complications, an urgent chest CT should be performed if there is any doubt.

The treatment for such injuries typically involves surgery, requiring immediate consultation with a thoracic surgeon. In the interim, if the necessary expertise and equipment are present, intubating the patient with a tracheal tube that extends beyond the rupture can help stabilize their condition. After

Secondary survey

A detailed head-to-toe examination is performed only after the primary survey is completed and the patient's condition is stabilized. This examination aims to identify potentially life-threatening thoracic injuries, other chest injuries, and to begin planning definitive care. However, many of these injuries will have already been identified and their treatment initiated during the primary survey.

Beyond conducting routine investigations during the secondary survey, such as X-rays, ECGs, and arterial blood gases, additional imaging methods like CT scans or angiography, and invasive monitoring might be necessary depending on the findings.

It's crucial to acknowledge that conditions uncovered in the secondary survey can evolve gradually. As a result, signs or symptoms may be negligible or not present soon after the injury. Hence, it's essential to perform repeated chest examinations and document the results, enabling future clinicians to detect any alterations.

Potentially life-threatening thoracic injuries

Pulmonary contusions

Thoracic trauma is commonly associated with a high incidence of pulmonary parenchymal injuries (>50%) , which often lead to compromised oxygenation. In adults, a direct impact can result in rib fractures and contusions, typically near the lung area adjacent to the fractures. It's common to see an associated pneumothorax or hemothorax. Clinically, patients may present with rapid and shallow breathing, and there might be signs of bruising or abrasions on the chest wall, with palpation tenderness. Normal percussion and auscultation findings of the chest, especially shortly after the injury, are possible.

As contusions evolve pathophysiologically over 24-48 hours, there is a reduction in lung compliance and the development of respiratory distress. Serial arterial blood gas analysis becomes critical to identify gradual decreases in PaO_2 due to increasing ventilation/perfusion mismatch. Consequently, meticulous evaluation of chest X-rays for signs of progressive lung contusions is vital. These contusions might manifest distant from the direct impact site on the chest wall and may take several hours to become apparent on the chest X-ray.

Contusions typically resolve within several days, yet the normalization of gas exchange tends to be more gradual. With clinical deterioration, a thoracic CT scan may be beneficial to determine the full extent of lung damage. Additionally, repeated thoracic CT scans can assist in managing and monitoring the recovery of patients with substantial thoracic injuries who need ventilatory support.

Blast injuries can cause diffuse bilateral infiltrates in the lung field, often with associated pneumothoraces and/or pneumomediastinum. In patients with traumatic asphyxia, the radiographic appearance is typically due to widespread interstitial hemorrhage accompanied by pulmonary edema.

Initial management consists of warmed, humidified oxygen, careful fluid resuscitation, and observation, preferably in a critical care area. Some cases may be managed using non-invasive ventilatory support, provided adequate oxygenation and effective analgesia are possible. Patients with refractory hypoxia and overt respiratory failure will require intubation and ventilation using a lung protective strategy.

The criteria to determine the necessity for ventilation differ among units, and examples are provided in the table (). Blast lung injury poses a risk of systemic air embolism, especially when positive pressure ventilation is used. This consideration is crucial in the management of patients who have sustained severe injuries from explosions.

• Decreased level of consciousness
• Elderly
• Poor analgesia and inability to clear secretions
• Increasing $PaCO_2$
• Decreasing PaO_2
• General anaesthesia required for surgery
• Transfer required
• Severe pre-existing lung disease

Table 3.3: Indications for invasive ventilation following pulmonary contusion

Pulmonary lacerations

Pulmonary lacerations are typically caused by penetrating thoracic trauma, but they can also result from blunt injuries with a heavy impact. These injuries are invariably accompanied by a pneumothorax, hemothorax, or hemopneumothorax and, in the case of blunt trauma, pulmonary contusion. Management of these injuries follows the principles already described. Approximately 5% of these patients will require a formal thoracotomy, particularly if there is persistent bleeding, air leakage, or hemoptysis.

Blunt cardiac injury

Blunt cardiac injury encompasses a spectrum of conditions, ranging from minor ECG and/or lab abnormalities to septal, free wall, or valvular rupture. As a pathological diagnosis, it lacks a precise clinical definition. The key clinical considerations are identifying patients at risk of clinically significant blunt cardiac injury, detecting the consequences (e.g., arrhythmias, myocardial dysfunction), and managing the condition to prevent adverse outcomes. These patients are typically exposed to major forces (e.g., a road traffic collision) and often have other associated injuries.

Blood troponin levels have improved the specificity of detecting blunt cardiac injury compared to conventional markers. However, troponin has low sensitivity and predictive value for diagnosing myocardial contusion and is not reliable for diagnosing the condition in hemodynamically stable patients. Therefore, an elevated troponin level should be interpreted in the context of the patient's injuries and clinical condition.

Current guidelines suggest the following: An initial ECG is mandatory for all patients when blunt cardiac injury is suspected. An abnormal ECG (indicating arrhythmia, ST or T wave changes, ischemia, heart block, or unexplained T wave inversion) necessitates the patient's admission for continuous ECG monitoring over a period of 24-48 hours.

If the initial ECG is normal and the likelihood of a clinically significant blunt cardiac injury is minimal, no further diagnostic procedures are required. In cases of hemodynamic instability, appropriate imaging should be acquired. Should a satisfactory transthoracic echocardiogram be unattainable, a transesophageal echocardiogram becomes essential. Although rare, late complications such as arrhythmia, aneurysm, and heart failure have been documented.

Ruptured diaphragm

Diaphragmatic ruptures can result from both blunt and penetrating trauma. Road traffic collisions are the most common cause of blunt trauma, with side impacts leading to three times as many diaphragmatic injuries as frontal impacts. The left hemidiaphragm is more susceptible to damage than the right, likely due to the liver's cushioning effect. Thus, injuries on the right side suggest severe trauma and a possible liver injury.

Around 20% of penetrating thoracic injuries extend to the diaphragm, and among these, 75% coincide with injuries within the abdomen. Injuries to the left side occur more frequently, which may be attributed to the oversight of minor right-sided injuries or the predominance of right-handed assailants.

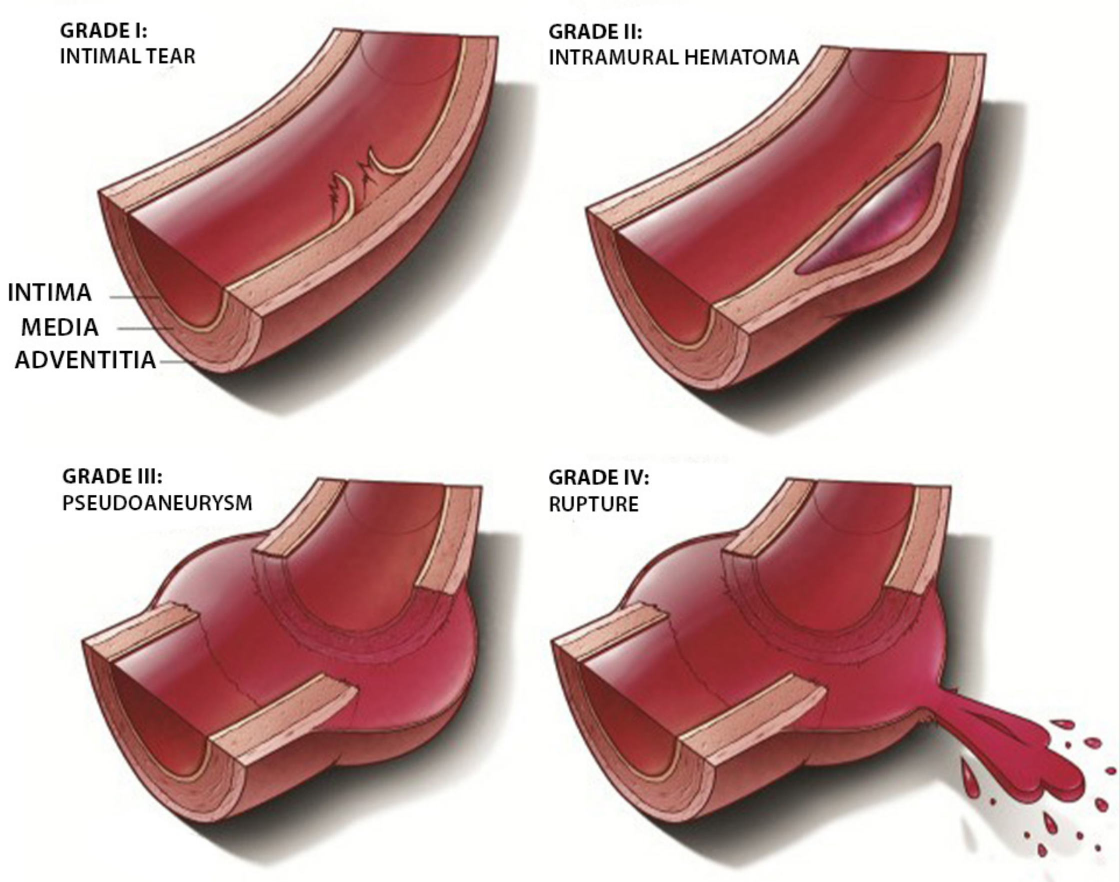
Many diaphragmatic injuries present without symptoms, making the injury's proximity the most indicative sign. Occasionally, one may observe decreased breath sounds on the injured side, or peritoneal fluid escaping through a chest drain as additional indicators.

Typically, an abnormal chest X-ray first raises suspicion, followed by a CT scan of the thorax to determine the tear's size and location. Regardless of the cause, herniation of abdominal organs into the chest cavity can result in respiratory distress and, sometimes, an acute abdomen due to the strangulation of bowel loops. Consequently, surgical repair is imperative for diaphragmatic ruptures.

Aortic rupture/great vessel injury

In approximately 85% of cases, aortic injury occurs in victims subjected to rapid deceleration, such as high-speed road traffic collisions or falls from significant heights. The remaining cases result from penetrating trauma or crush injury. During deceleration, the aortic injury most commonly occurs near the ligamentum arteriosum, just distal to the origin of the left subclavian artery. At this point, the descending aorta is relatively fixed while the heart remains mobile within the mediastinum, creating a site of maximal shearing forces. Other vulnerable sites include the aortic root and the level of the diaphragm, where the aorta is relatively immobile.

CLASSIFICATION OF TRAUMATIC AORTIC INJURY



The clinical presentation of aortic rupture depends on the injury site. Injuries to the intrapericardial portion of the ascending aorta typically lead to cardiac tamponade. An extrapericardial ascending aortic injury produces a mediastinal hematoma and a hemothorax, usually on the right side. Injuries to the aortic arch may initially go undiagnosed if the adventitia remains intact, containing the damage as a mediastinal hematoma.

As a result, patients may display transient hypotension, which often responds favorably to fluid therapy. This can lead to a delayed diagnosis, with devastating consequences if the aorta fully ruptures. It is critical to maintain a high level of suspicion and to use appropriate diagnostic tools judiciously.

Aortic disruption should be suspected in cases of rapid deceleration, upper body hypertension (relative to the lower body), or the presence of high-energy transfer markers to the upper thorax (e.g., fractures of the 1st-3rd ribs).

In a conscious patient, symptoms may encompass intense retrosternal discomfort, interscapular pain, hoarseness (resulting from hematoma pressure on the recurrent laryngeal nerve), difficulty swallowing (due to esophageal compression), and paraplegia or paraparesis (due to compromised blood vessels serving the spinal cord). Furthermore, ischemia or infarction may occur in other regions, such as the limbs and abdominal organs, along with possible fractures of the ribs or sternum.

A plain chest X-ray may provide clues, but it is important to recognize that plain X-rays lack both sensitivity and specificity. If clinical suspicion exists, a CT angiogram (or angiography, depending on local policy) is required. When these symptoms and signs are present, investigations for aortic injury and consultation with a cardiothoracic surgeon are mandatory, as delays can lead to profound hypotension and death. If there is sufficient suspicion, patients should be managed as having an aortic injury until confirmatory diagnosis with a chest CT. Blood pressure control is paramount in these cases to prevent further disruption or rupture of the aorta. Invasive blood pressure monitoring is necessary to detect subtle changes in the hemodynamic condition.

• Mediastinum wider than 8 cm
• Pleural cap (apical hematoma) especially on the left
• Compression and downward displacement of the left main bronchus
• Fractured first or second rib
• Trachea shifted to the right
• Opacification between the aorta and the left pulmonary artery
• Blunting of the aortic knuckle
• Raised right main bronchus
• Left haemothorax with no obvious rib fractures or other cause
• Deviation of the nasogastric tube to the right

Table 3.4: Chest X ray findings in descending thoracic aorta rupture

Oesophageal injury

Injuries to the thoracic esophagus are rare because it is well-shielded within the posterior mediastinum. However, the cervical region is more susceptible to damage from penetrating trauma or a crush injury. Further down, the esophagus is vulnerable to rupturing from a severe impact to the epigastrium.

A leak from an esophageal injury can lead to mediastinitis, often presenting as shock and severe pain disproportionate to the apparent injuries, which is a key diagnostic clue. Pain on swallowing also suggests esophageal injury and must be investigated. The presence of a left-sided pneumothorax, effusion, or pneumomediastinum without rib fractures should raise suspicions. Depending on the site of rupture, surgical emphysema or signs of peritonitis may develop over time.

Other injuries in thoracic trauma

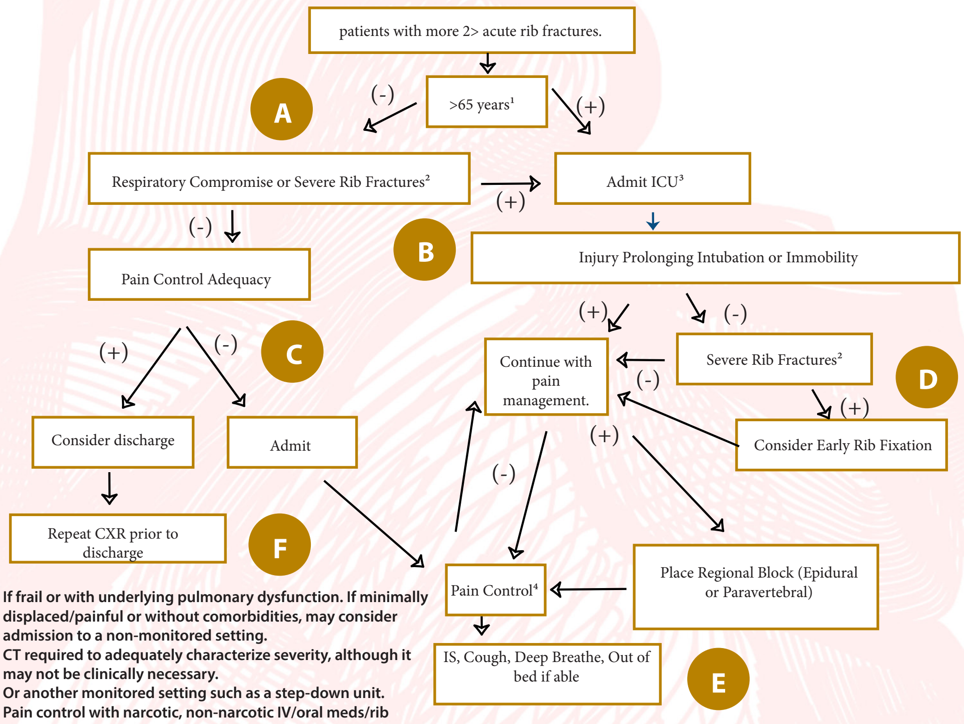
Rib and sternal fracture

Rib injuries and fractures frequently occur in thoracic trauma. Multiple rib fractures often come with different levels of lung contusion. Besides the damage to lung tissue, the pain can restrict breathing, and the patient might not be able to cough effectively, which raises the risk of developing a pulmonary infection.

Fractures of the first three ribs suggest a high-energy impact and necessitate a comprehensive search for additional injuries, including aortic injury, severe pulmonary contusion, or airway rupture. Fractures of the lower ribs heighten the risk of liver and spleen injuries. Fractures of other bones, such as the sternum, clavicle, or scapula, may indicate a flail segment, requiring a reevaluation of the ribs. It is crucial to note that initial chest X-rays may only reveal about 50% of rib fractures.

If a chest X-ray reveals a sternal fracture, a CT scan or lateral chest film is recommended, in accordance with local policy, to verify displacement. In the absence of displacement, patients can be observed for 24 hours. If displacement is detected, it is important to measure troponin levels. Elevated troponin levels indicate the need to treat the patient for a cardiac contusion. Echocardiography is also advised to detect any regional wall motion abnormalities. A chest CT scan can further assist in evaluating potential injuries to other mediastinal structures.

Algorithm 3.2: Western Trauma Association rib fracture



1. If frail or with underlying pulmonary dysfunction. If minimally displaced/painful or without comorbidities, may consider admission to a non-monitored setting.
2. CT required to adequately characterize severity, although it may not be clinically necessary.
3. Or another monitored setting such as a step-down unit.
4. Pain control with narcotic, non-narcotic IV/oral meds/rib blocks

Simple pneumothorax

Patients with a simple pneumothorax may exhibit sharp chest pain, particularly upon inspiration, although it's important to note that rib fractures can present in a similar manner. The level of respiratory distress can vary based on the size of the pneumothorax, any associated rib fractures, and whether there is a lung contusion. Suspect a pneumothorax if there is bruising or a penetrating wound, along with reduced movement of the chest wall on the affected side. The affected side may also show hyper-resonance upon percussion, and breath sounds could be diminished or absent. Tachycardia may be observed, but without blood loss, hypotension should not be present.

Given that clinical signs may not be clear-cut, a chest X-ray should be performed when a pneumothorax is suspected. A typical apico-lateral pneumothorax is often invisible on the initial supine chest X-ray in up to 30% of cases because the air will be lying anterior to the lung Consequently, CT is increasingly used in the diagnosis of pneumothorax. However, its greater sensitivity must be balanced against detecting small pneumothoraces that may not be clinically relevant in a non-ventilated patient.

The management of an occult pneumothorax, which is not visible on a chest X-ray but is evident on a CT scan, typically involves the placement of a chest tube in a patient on mechanical ventilation. The same approach is often adopted for spontaneously breathing trauma patients.

However, the decision to place a chest tube must take into account the patient's overall condition, the pneumothorax size, any associated injuries, and the planned definitive treatment. In cases where surgery or intubation is not necessary, conservative management of an occult pneumothorax may be suitable. Under this approach, vigilant monitoring is essential to promptly identify any early indicators of respiratory distress.

Haemothorax

A hemothorax can be diagnosed on an erect radiograph by the obliteration of the costophrenic angle, which requires the presence of 300-400 ml of blood. In supine patients, this amount of blood may not be immediately obvious; often, the only clue is a generalized decrease in radiolucency in one hemithorax. In contrast, a massive hemothorax will result in a unilateral whiteout, and a large hemopneumothorax may present with an air-fluid level on an erect film.

Treatment for this condition involves chest tube drainage, as retaining a significant amount of blood in the pleural cavity can lead to pulmonary contracture and an increased risk of empyema.

Air embolism

This condition, though rare, can be life-threatening and may arise from both blunt and penetrating trauma, especially after a lung blast injury. Patients with a patent foramen ovale are at risk of paradoxical systemic embolism if a right-sided air embolus occurs.

Treatment until a thoracotomy can be organized includes:

- Nursing the patient in a head-down position
- Expanding the intravascular space through fluid resuscitation
- Increasing systemic arterial pressure using inotropes and/or vasopressors
- Ventilation with 100% oxygen
- Reducing the tidal volume of the ventilator to lower intrathoracic pressures

Despite these interventions, mortality remains high, especially due to the neurological consequences of air entering the cerebral vascular system.

CHAPTER FOUR

SHOCK

Learning Objectives:

At the end of this chapter, the reader will be able to :

- Identify trauma victims in shock and shock related causes.
- Assess and monitor the trauma patient in shock.
- Know how to implement hemorrhage control protocol.
- Resuscitate the trauma patient in shock.

Introduction

Shock refers to a critical condition where organs and tissues suffer from insufficient oxygen supply, posing a severe threat to life. This occurs due to an imbalance between oxygen delivery and consumption.

Initially, this imbalance primarily results from impaired delivery (hypoperfusion), commonly due to hypovolemia in trauma patients. Subsequently, as shock progresses, there is an elevation in oxygen uptake due to stress, inflammation, or sepsis, each of which amplifies oxygen requirements beyond healthy levels.

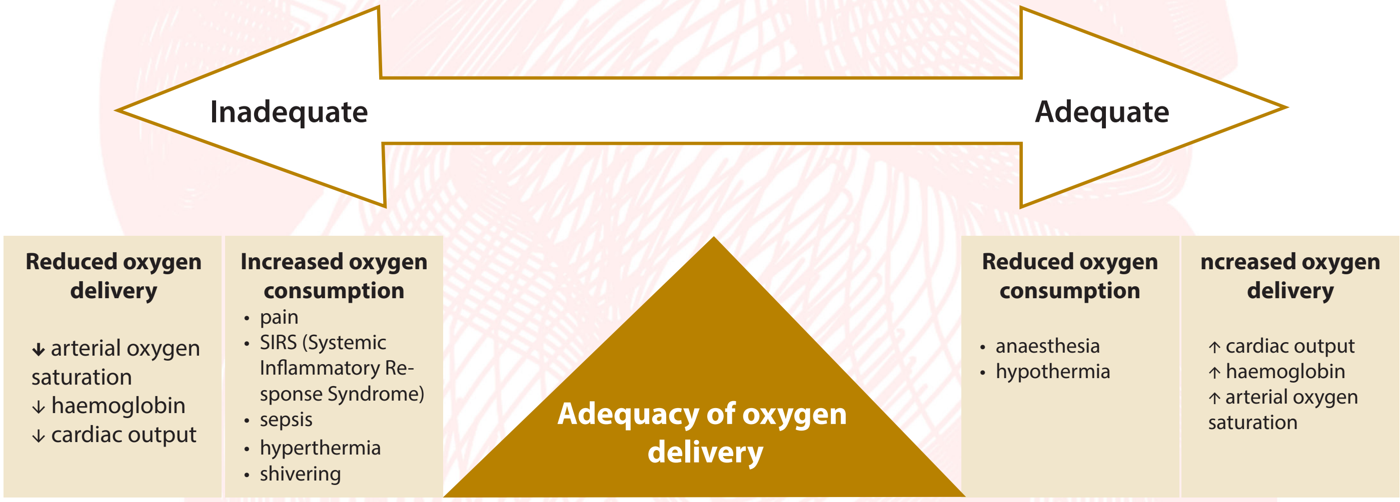


Figure 4.1: factors affecting the oxygen delivery and consumption

The Causes of shock

While hypovolemia stands as the primary cause of shock in trauma cases, there may also be additional underlying disorders affecting oxygen delivery. These conditions can ultimately result in cellular hypoxia, dysfunction of microcirculation or mitochondria, and cell death. If not addressed, this triggers the release of various mediators, initiating a systemic inflammatory response syndrome. In cases of multisystem trauma, these effects compound.

Table 4.1: Shock types

Type of shock	Examples of causes	Effect on cardiac output
Hypovolaemic	Haemorrhage, interstitial (third space) losses, burns, dehydration	Decreased
Obstructive	Tension pneumothorax, cardiac tamponade, massive pulmonary embolus	Decreased
Cardiogenic	Myocardial injury or ischaemia	Decreased
Distributive:		
▪ Neurogenic	Spinal cord injury (usually above T6)	Decreased
▪ Septic	Pneumonia, bowel perforation, infection (late complication of trauma), delayed resuscitation	Decreased, normal, or increased
▪ Anaphylactic	Acute allergic reaction (type I hypersensitivity)	Normal or decreased

Recognition of shock

Detecting shock in trauma patients requires an in-depth assessment of their symptoms and lab results. No single vital sign or test can conclusively diagnose shock on its own.

Quickly identifying poor tissue perfusion depends on recognizing typical clinical signs in trauma patients.

Clinical examination

signs of external or internal hemorrhage.

Estimating the volume of blood lost

- heart rate;
- blood pressure;
- respiratory rate;
- capillary refill time;
- skin colour and temperature;
- urine output;
- conscious level.

Metabolic disturbances (blood gases)

pH;
lactate;
base deficit.

Individually, these changes aren't precise indicators of the decrease in blood volume due to the presence of factors that influence how trauma victims react to hypovolemia.

Factors affecting estimation of blood loss

Pre-existing medical conditions

The reaction to trauma varies among patients. Individuals with limited cardiorespiratory capacity due to conditions like ischemic heart disease, valve problems, or neuropathy (such as in diabetes) struggle to cope with sudden blood loss. Consequently, even minor blood loss can cause a drop in blood pressure, making it seem like more blood has been lost than actually has.

Conversely, if the patient typically has high blood pressure, bleeding might only bring their blood pressure down to a normal level for their age, which could make it seem like less blood has been lost than actually has.

Drugs and pacemakers

Different medications can change how the body responds to blood loss, such as β-blockers. Illicit drugs like cocaine can also interfere with the normal bodily response. The impact of a pacemaker depends on its complexity; some may maintain a steady pace (around 70-100 beats per minute) regardless of blood volume or arterial pressure, leading to mistakes in estimating blood loss.

It's important to consider if the patient is on blood thinners, which can be determined through their medical history, a medic alert bracelet, or early assessment of clotting function. Any abnormalities should be addressed promptly, especially in patients who are actively bleeding or have brain injuries.

The athlete

In athletes, the normal resting heart rate can be below 50 beats per minute, and they may have a higher blood volume, increased by about 15-20%. Consequently, a rapid heart rate signaling significant acute blood loss may be less than 100 beats per minute.

The patient with hypothermia

When the core body temperature drops below 35°C, it can lower arterial blood pressure, heart rate, and breathing rate independently of any blood loss. If this is overlooked, it might lead to an overestimation of hypovolemia.

Hypothermic patients who are also experiencing hypovolemia may not respond well to standard fluid replacement. Estimating the fluid needs of these patients can be quite challenging, often requiring invasive monitoring of their hemodynamics.

Penetrating or blunt trauma

Minor tissue damage, often seen with a penetrating injury like a stab wound, initially leads to rapid heartbeat and vasoconstriction. At first, this might keep blood pressure relatively normal. However, as blood loss continues, the heart rate slows down, sympathetic nerve activity decreases (especially in muscles and kidneys), and blood pressure drops significantly.

On the other hand, major tissue damage, such as from blunt trauma with fractures, causes ongoing and increasing rapid heartbeat and intense vasoconstriction in non-essential organs like the intestines and skin. Despite ongoing blood loss, these patients keep compensating.

Eventually, when blood loss reaches a certain point, the body can't compensate anymore, and low blood pressure occurs. This is a late warning sign that cardiovascular collapse is imminent.

Primary survey and resuscitation

The initial management of a shocked patient is centered on addressing the lethal triad., by:

- Preventing further bleeding;
- Ensuring sufficient oxygen is delivered;
- Minimizing additional heat loss and initiating rewarming;
- Identifying and rectifying any coagulation disorders.

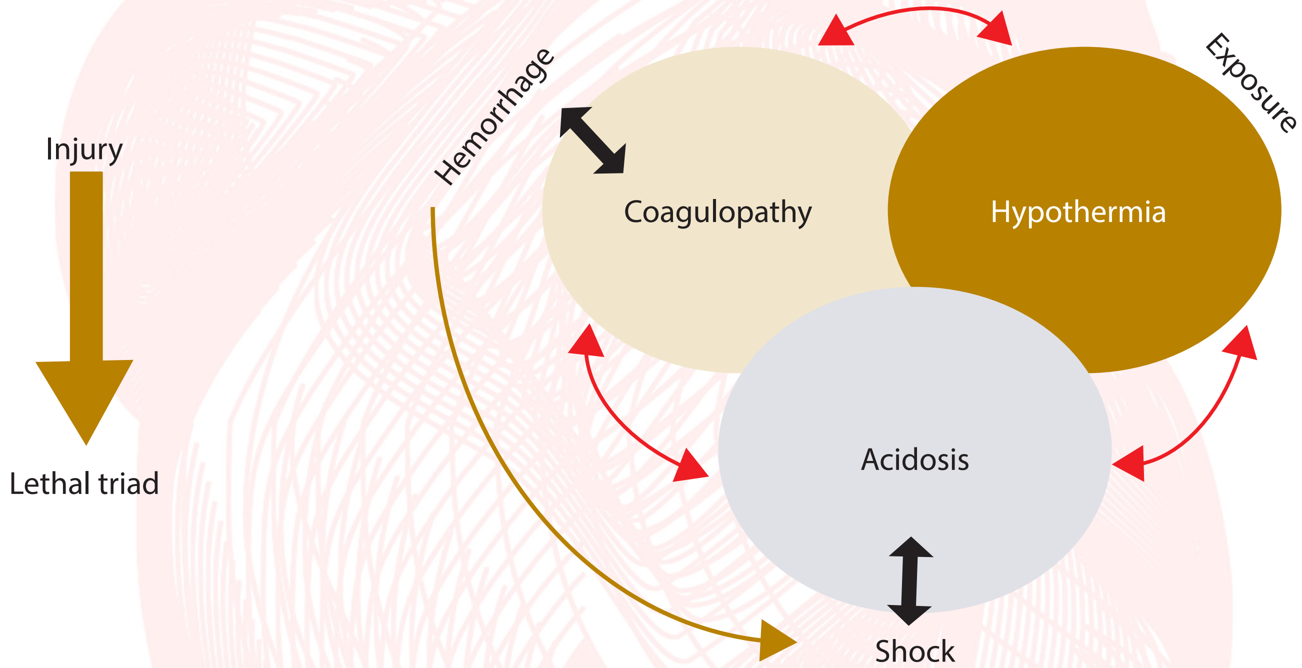


Figure 4.2: Lethal Triads of trauma

The main goal in trauma care is to accomplish these tasks as quickly as possible, ideally within the first hour. Therefore, these actions should be taken while the patient is moved from the pre-hospital setting to the resuscitation area, and then to other necessary locations like the CT scanner, operating room, radiology suite, or intensive care unit.

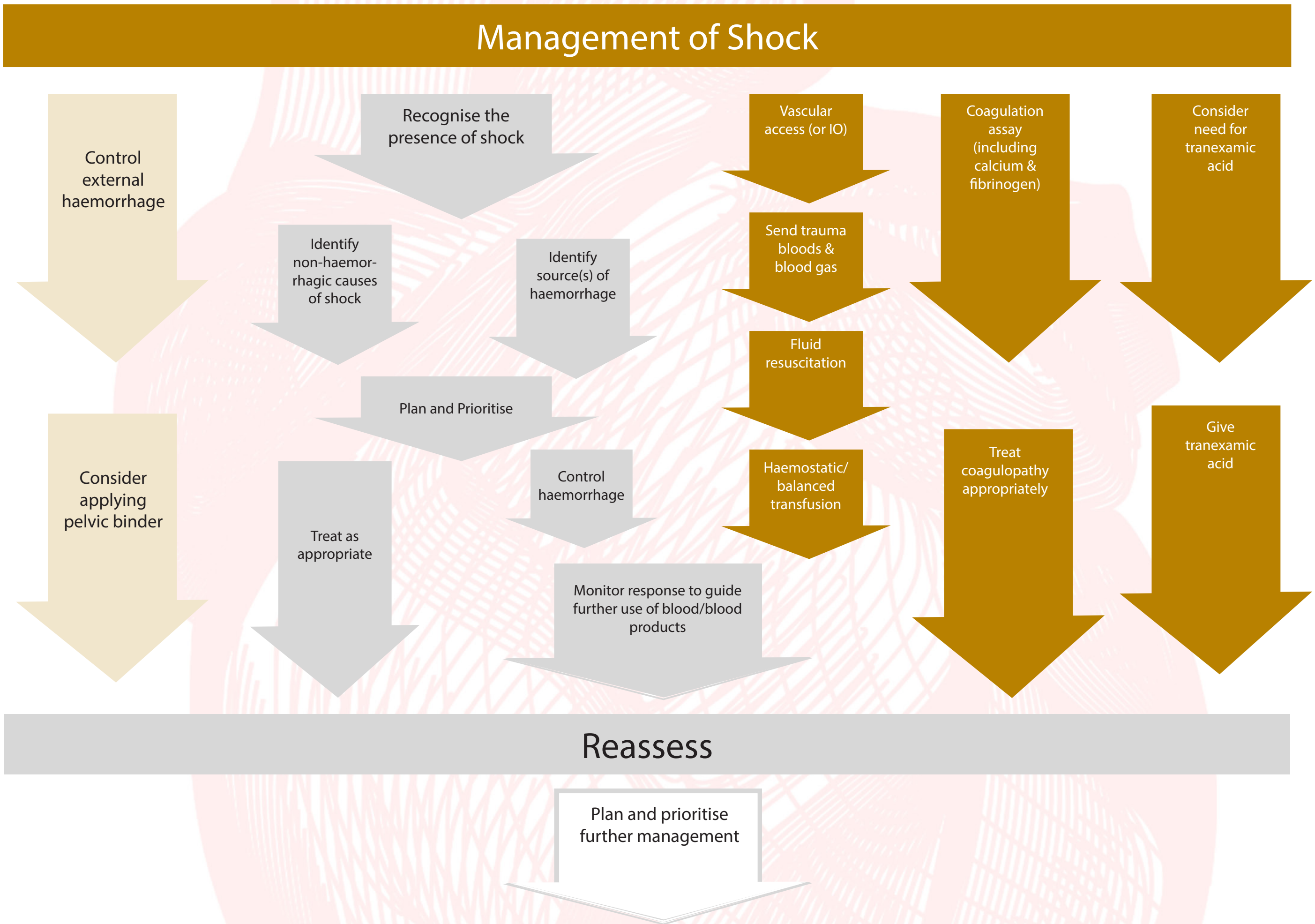
Before the patient arrives:

It's crucial to be well-prepared based on information gathered from the pre-hospital setting. This includes making sure that:

- The resuscitation room is warm.
- Intravenous fluids are warmed.
- The blood warmer is ready.
- Warming blankets are on hand.
- Tranexamic acid is accessible.
- The major bleeding protocol is activated correctly.
- A team briefing has been conducted.

On arrival

Algorithm 4.1: Management of shocks



Hemorrhage control in the resuscitation room

In the resuscitation room, methods to manage bleeding include:

- Direct pressure at the bleeding site.
- Using hemostatic dressings to promote clotting.
- Applying tourniquets for bleeding from limbs.
- Using splints to reduce blood loss from broken long bones.
- Applying a pelvic binder if a patient is unstable and suspected to have a pelvic fracture.

Vascular access

It's important to get access to the blood vessels by putting in two large peripheral IV lines (14 or 16 gauge). If it's not possible to use peripheral veins or if attempts fail, other options include inserting a central venous access (such as the subclavian, internal jugular, or femoral veins) or using intraosseous (IO) access.

Hemorrhagic classifications

Table 4.2: Signs and symptoms of hemorrhage by class

PARAMETER	CLASS I (<15%)	CLASS II (MILD) (15-30%)	CLASS III (MODERATE) (31-40%)	CLASS IV (SEVERE) (>40%)
Approximate blood loss	<15%	15-30%	31-40%	>40%
Heart rate	↔	↔/↑	↑	↑/↑↑
Blood pressure	↔	↔	↔/↓	↓
Pulse pressure	↔	↓	↓	↓↓
Respiratory rate	↔	↑	↑/↑↑	↑↑
Urine output	↔	↔	↓	↓↓
Glasgow Coma Scale score	↔	↔	↓	↓↓
Base deficit*	0 to -2 mEq/L	-2 to -6 mEq/L	-6 to -10 mEq/L	≤ -10 mEq/L
Need for blood products	Monitor	Possible	Yes	Massive Transfusion Protocol

*Note: Base excess is the quantity of base (HCO_3^-) in mEq/L that is above or below the normal range in the body. A negative number is called a base deficit and indicates metabolic acidosis.

Fluids and blood products for resuscitation

Crystalloids

The most commonly used crystalloid solutions include Ringer's lactate, and 0.9% saline.

Hypertonic crystalloid solutions, like hypertonic saline, are recommended for initial resuscitation of patients with traumatic brain injury, as they may reduce brain swelling and pressure, improving blood flow to the brain and decreasing nerve damage.

Blood and blood products

For unstable trauma patients with low blood volume, warmed blood products are the preferred fluids for resuscitation. Stored blood is usually processed into various products to ensure the most appropriate one can be administered.

Initially, packed red blood cells (PRBCs) are typically given to restore hemoglobin levels. These lack clotting factors and platelets. While ideally all blood transfusions should undergo a full compatibility check (crossmatch), this process can take up to an hour. In urgent situations, uncrossmatched O-negative blood may be used. Type-specific blood should be used as soon as it's available to ensure compatibility between the recipient and donor blood (ABO and Rh).

In cases of ongoing bleeding or significant blood loss, PRBCs should be supplemented with fresh frozen plasma (FFP), clotting factor concentrate, cryoprecipitate, and platelets. This is best done through a massive transfusion protocol (MTP), which has become standard for resuscitating patients physiologically affected by blood loss or ongoing bleeding.

All fluids should be warmed before administration to prevent inadvertent cooling of the patient (hypothermia). This is typically done by storing crystalloids in a warming cupboard and using warming devices during administration to minimize heat loss. Rapid infusion devices capable of delivering large volumes of warmed blood products or fluids should be available for resuscitating severely shocked patients.

Identifying the causes of shock

The initial assessment aims to not only detect shock but also its underlying causes. Extended Focused Assessment with Sonography in Trauma, known as eFAST, can quickly reveal the cause of shock in patients who are unstable hemodynamically.

eFAST helps direct resuscitation efforts toward the affected area, allowing for early decisions regarding damage control surgery. In cases of abdominal trauma, the presence of free fluid on ultrasound indicates intraabdominal bleeding, often from sources like a ruptured spleen or liver.

Early CT scanning is the preferred diagnostic method, and Whole Body scanning is now integrated into the primary survey in many advanced trauma care systems. Performing these scans immediately upon assessment seems to improve survival rates.

Seven famous places for hemorrhagic shock in trauma from head to toe with its evaluation:

- External bleeding from the Scalp (eyeball exam)
- Thoracic cavity (Eyeball exam, CXR and E-FAST)
- Abdominal (Peritoneal) cavity (Eyeball exam, palpation and E-FAST)
- Pelvis (Eyeball exam, Pelvic stabilization exam and E-FAST)
- Retroperitoneum (THE ONLY ONE THAT NEED CT SCAN)
- Long bone fracture (Eyeball exam and X-ray)
- Other external bleeding (Eyeball exam)

All of the bleeding sites can be identified at the trauma bay before moving the pt to imaging except for the retroperitoneal bleeding.

Damage control resuscitation

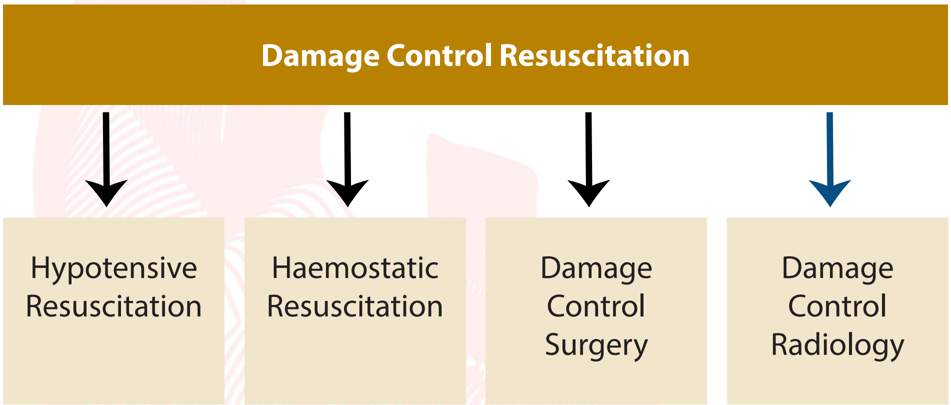


Figure 4.3: Damage control resuscitation strategies

When there is ongoing uncontrollable bleeding and can't be controlled, the team leader must consider the need for damage control resuscitation. The concept of damage-control resuscitation has been developed with the aim of providing optimal fluid resuscitation and transfusion to patients with hemorrhagic shock secondary to severe trauma. The goal of damage-control resuscitation is to minimize iatrogenic resuscitation injury, to prevent worsening of initial traumatic shock, and to obtain definitive hemostasis.

This involves a combination of strategies including permissive hypotension, hemostatic resuscitation, performing damage control surgery, and using interventional radiology.

Permissive hypotension:

The concept of "permissive hypotension" refers to managing trauma patients by restricting the amount of resuscitation fluid and maintaining blood pressure in the lower than normal range if there is continuing bleeding during the acute period of injury. This treatment approach may avoid the adverse effects of early, high-dose fluid resuscitation, such as dilutional coagulopathy and acceleration of hemorrhage, but does carry the potential risk of tissue hypoperfusion.

Haemostatic resuscitation

Haemostatic resuscitation describes the process of restoring and sustaining normal tissue perfusion to the patient presenting in uncontrolled haemorrhagic shock, with an emphasis on preservation of effective clotting.

Provides resuscitation with blood components resembling whole blood with the aims of

- maintain circulating volume
- limit ongoing bleeding, and
- prevent the lethal trial of hypothermia, acidosis and acute coagulopathy of trauma

Damage control surgery (DCS)

Damage control as an entity focuses on restoring patient physiology rather than anatomy, and involves the rapid time-limited control of haemorrhage and contamination.

Obvious vessel bleeding can be controlled by ligation, shunting (Figure 3), or repair of injured vessels as they are encountered. There are few sequelae to ligating the internal iliac, axillary, subclavian, external carotid or common carotid arteries.12 For the patient in extremis, simple clamping or shunting of major vessels only is performed. During damage control laparotomy only essential resections are performed foregoing primary anastomosis.

Injured solid organs are packed based on the principle that pressure stops bleeding, and pressure vectors should re-create the tissue planes created by the capsule of the organ, and not randomly placed. Major extremity and pelvic fractures should have rapid external fixation applied with control of vascular injuries and fasciotomies.

Damage Control Interventional Radiology (DCIR)

Interventional radiology plays a crucial role in the management of emergency and trauma patients (both blunt and penetrating injuries) and has allowed minimally invasive treatment of patients by careful case selections and multidisciplinary team planning involving surgeons and anesthesiologists. In the damage control context, three different interventional techniques are used to control bleeding: temporary balloon arterial occlusion, embolization to occlude arteries (which can be either temporary or permanent), and stent grafting to repair injured vessels restoring normal flow. The golden rule of DCIR is to embolize vessels as selectively as time allows.

The objective of DCIR is to confine the ongoing hemorrhage as quickly as feasible in order to maintain or restore normal hemodynamics, rather than to conduct a distal, time consuming, embolization. In this view, all procedures from catheterization to the final visual confirmation of embolization should be completed within a 10-min window for each targeted vessel .

For unstable patients, aggressive non-selective embolization (NSE) is preferred despite the possibility of losing vital organs.

There are three main types of patients who may need this approach.

1. Penetrating trauma

Patients with penetrating trauma and minimal tissue damage may continue to bleed into a body cavity, a process that external measures cannot halt. Aggressive resuscitation involving rapid infusion of large fluid volumes can raise arterial blood pressure but may also dislodge a formed blood clot and dilute clotting factors, potentially causing further bleeding. The immediate priority for these patients is to halt the bleeding, either through surgery (damage control surgery) or radiology, depending on the location of the hemorrhage and the local resources available.

Only necessary tests should be conducted to prevent delays in surgical or radiological interventions, thereby minimizing the duration of shock for the patient. In the absence of a head injury, fluid resuscitation prior to any intervention should aim to preserve organ function temporarily, with an appropriate target systolic blood pressure (SBP) of 80-90 mmHg. Hypotensive resuscitation is a temporary measure used until bleeding is controlled. After achieving hemostasis, the patient should receive further resuscitation to reestablish normal oxygen delivery and circulatory functions.

2. Blunt trauma

This usually results in injuries to soft tissues and/or bones, which require imaging tests like x-rays, ultrasound, or CT scans. As mentioned before, hypotension in these patients signals a need for more aggressive treatment to minimize tissue damage and prevent the later onset of inflammatory response syndrome and organ failure. If there's no head injury, these patients may benefit from permissive hypotensive resuscitation, aiming for a target systolic blood pressure (SBP) of 80-90mmHg.

3. The complex patient - Traumatic Brain and Spinal Cord Injuries

In cases where a patient has both traumatic brain injury and significant, uncontrolled bleeding, it's advisable to aim for a mean arterial pressure (MAP) above 80 mmHg (or a systolic blood pressure around 100 mmHg) in the short term.

This is because even brief periods with a systolic blood pressure below 90mmHg significantly increase mortality in traumatic brain injury patients. Surgical or radiological procedures should be carried out as quickly as possible to control the bleeding. Resuscitating the brain injury takes precedence, with most experts recommending aiming for a MAP above 90mmHg. When intracranial pressure monitoring is in place, blood pressure should be adjusted to ensure adequate cerebral blood flow.

For patients with isolated traumatic brain or spinal cord injuries, specific resuscitation goals are used. Some patients may present with high blood pressure and bradycardia. This high blood pressure is the body's attempt to maintain blood flow to the brain despite increased intracranial pressure. No action should be taken to lower it. Initially, isotonic fluids should be given at a standard rate. Otherwise, the goal is to maintain a systolic blood pressure above 110mmHg, a MAP above 90mmHg, or normal blood pressure if the patient is known to have hypertension. These same targets apply to patients with isolated spinal cord injuries.

Evaluating the patient's reaction to fluid resuscitation

1-The patient is improving

This indicates that the body's natural response mechanisms and the speed at which fluids are given are enough to offset the rate of blood loss. These patients may need packed red blood cells (PRBCs) later, but it's okay to wait until a full compatibility check is done. It's important to closely monitor vital signs and promptly inform the team leader of any sudden worsening of the patient's condition.

2- The patient initially shows improvement but subsequently deteriorates.

In such situations, the bleeding rate may have increased due to either a new bleeding source or loss of clotting at the original site. The latter could be caused by excessive fluid resuscitation leading to a rise in blood pressure. These patients need urgent evaluation by a surgeon, with many requiring surgery or interventional radiology.

Blood transfusion, usually packed red blood cells (PRBCs), is also necessary, with the choice between using group O, type-specific, or fully crossmatched blood. Blood transfusion should be balanced with fresh frozen plasma (FFP) and platelets, with clotting regularly monitored. The ongoing treatment plan will depend on the patient's clinical condition and the results of investigations.

3-The patient does not improve

Patients may be losing blood more rapidly than they can be resuscitated with fluids or blood, or they may be suffering not only from hypovolemic shock but also from other types such as cardiogenic or neurogenic shock. A thorough review of their medical history, physical examination, and vital signs is essential to differentiate between these conditions.

Those experiencing massive ongoing bleeding will need immediate intervention with continuous resuscitation, often known as "damage control surgery." For this group, activating the massive transfusion protocol (MTP) is essential, which involves early use of balanced blood transfusions, correction of blood clotting abnormalities, and prevention or treatment of hypothermia. These can be guided by thromboelastography or thromboelastometry if available.

The goal is to provide blood products in a ratio similar to whole blood, ensuring adequate clotting factors and platelets. Trauma-induced coagulopathy is characterized by a deficiency of fibrinogen, and early replacement of fibrinogen improves survival.

Surgical and radiological management of haemorrhage – damage control surgery and radiology'

Damage control surgery aims to control bleeding with minimal intervention while ongoing resuscitation, rewarming, and correction of any blood clotting issues are carried out. It's not in the patient's immediate best interest to undergo prolonged, definitive general or orthopedic surgery while they are cold, have blood clotting issues, and are acidic.

During surgery, the focus is on cleaning and stabilizing fractures externally, stopping bleeding, closing perforated bowel with staples, rinsing the abdominal cavity, packing it, and leaving it open (laparostomy) for later closure. After surgery, the patient is taken to the intensive care unit (ICU) for stabilization, after which further surgical procedures can be planned.

Interventional radiology in the trauma patient

After appropriate imaging has identified the bleeding source, the trauma team, including the interventional radiologist and surgeon, should decide on the best approach: non-operative management, interventional radiology, damage control surgery, or a combination. This decision should be based on all available information, including clinical and logistical factors.

Major hemorrhage protocols

Most current protocols recommend giving packed red blood cells (PRBCs) and fresh frozen plasma (FFP) at a ratio between 1:1 and 2:1, along with the right amount of platelets. It's important to check fibrinogen levels and provide cryoprecipitate or fibrinogen concentrate to support strong blood clotting. This method ensures that resuscitation with blood products stops bleeding and minimizes the risk of developing coagulopathy. When to administer FFP and platelets will vary depending on local protocols.

Tranexamic acid

Tranexamic acid should be administered to patients who are experiencing or are at risk of severe bleeding as part of their treatment, but it should be given within three hours of the injury. It's safe to give to patients with a head injury, but it's not recommended if a head injury is the only concern. The initial dose for adults is 1 gram given over 10 minutes, followed by an infusion of 1 gram over eight hours.

Coagulopathy in trauma

The importance of coagulopathy problems in trauma is often underestimated, with more than one-third of civilian and military trauma patients having abnormal clotting when they arrive at the resuscitation room. It's essential to measure a patient's PT, aPTT, platelet count, and fibrinogen levels, as well as their arterial blood gas, serum lactate, and ionized calcium levels. Point-of-care coagulation monitoring using techniques like thromboelastography (TEG) or rotational thromboelastometry (ROTEM) is becoming increasingly valuable for quickly identifying and correcting clotting problems during the acute phase. The causes of clotting problems are usually multifaceted.

The targets to achieve in the bleeding trauma patient include:

Hb 7 – 9g/dl;
platelets >100 x 109/l;
fibrinogen >1.5-2.0g/l;
ionised calcium >0.9mmol/l.

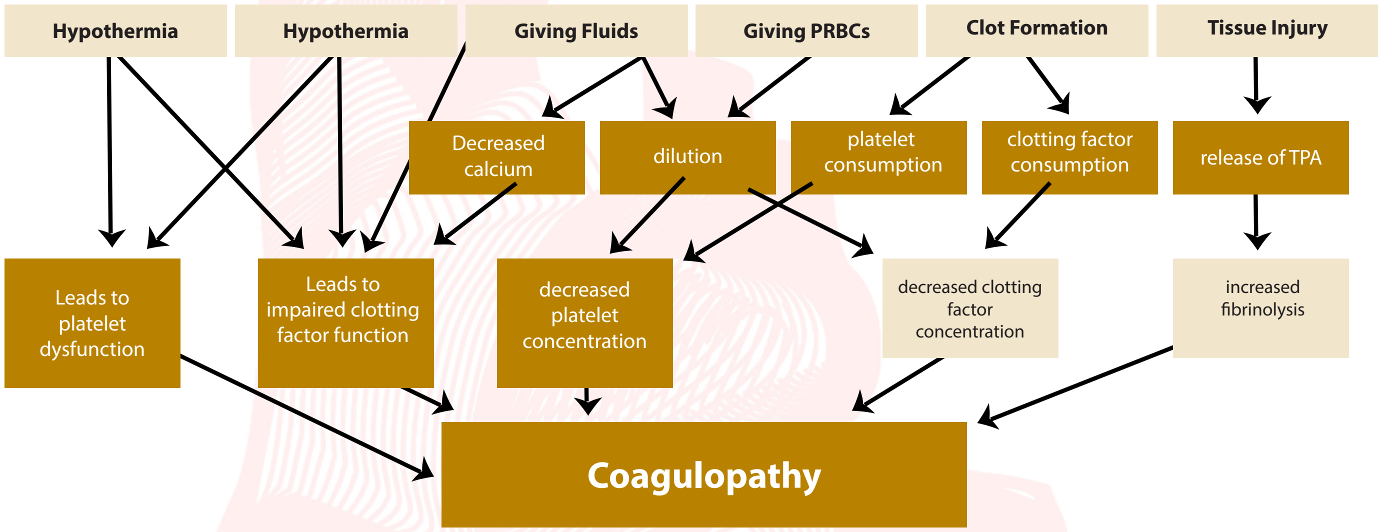
Table 4.3: Comparison of management of the trauma patient

Site of trauma	Non-operative	Interventional radiology	Damage control surgery
Thoracic aorta	No role except in small partial thickness tears	Stent graft for suitable lesions	Ascending aortic injury or arch injury involving great ves-sels
Abdominal aorta	No role	Occlusion balloon, stent graft for suitable lesions	Injury requiring visceral revascularisation or untreatable by endovascular aneurysm repair
Kidney	Subcapsular or retroperitoneal hematoma without active arterial bleeding	Active arterial bleeding: embolisation or stent graft	Renal injury in association with multiple other bleeding sites or other injuries requiring urgent surgical repair
Spleen	Lacerations, hematoma without active bleeding or evidence of false aneurysm	Active arterial bleeding or false aneurysm: - Focal embolisation for local lesion - Proximal embolisation for diffuse injury	Packing or splenectomy for active bleeding in association with multiple other bleeding sites
Liver	Subcapsular or intraperitoneal hematoma or lacerations without active arterial bleeding	Active arterial bleeding: - Focal embolisation if possible - Non-selective embolisation if multiple bleeding sites as long as portal vein is patent	Packing if emergency laparotomy needed with subsequent repeat CT and embolisation if required
Pelvis	Minor injury with no active bleeding	Focal embolisation for arterial injury (bleeding, false aneurysm or cut-off)	External fixation and subsequent packing if bleeding from veins or bones
Intestine	Focal contusion with no evidence of ischemia, perforation or hemorrhage	Focal bleeding with no evidence of ischemia or perforation. Or, to stabilise patient, allowing interval laparotomy pending treatment of other injuries	Ischemia or perforation requiring laparotomy ± bowel resection

Table 4.4: Major Haemorrhage Protocol

T	Tranexamic Acid	▸ If not given pre-hospital, administer within 3 hours of injury or continued hyperfibrinolysis: ▸ 1 g bolus, followed by ▸ 1 g infusion over 8 hours
R	Resuscitation	▸ Activate Major Haemorrhage Protocol ▸ Initial Transfusion Ratio 1:1:1 ▸ Consider: ▸ Rapid infusion and cell salvage ▸ Time-Limited hypotensive resuscitation ▸ Pelvic binder / splint fractures / tourniquet ▸ Avoid crystalloid use
A	Avoid Hypothermia	▸ Target temperature >36°C ▸ Remove wet clothing and sheets ▸ Warm blood products / fluids ▸ Use warming blanket / mattress
U	Unstable? Damage Control Surgery	▸ If unstable, coagulopathic, hypothermic, or acidotic, perform damage control surgery: ▸ Haemorrhage control, decompression, decontamination, splintage ▸ Aim surgery under 90 minutes and conduct regular surgical pauses
M	Metabolic	▸ Perform regular blood gas analysis ▸ Base excess guides resuscitation ▸ If lactate > 5mmol/L or rising, consider stopping surgery, splint, and transfer
A	Avoid Vaso Constrictors	▸ Inappropriate use of vasoconstrictors doubles mortality ▸ However, use cautiously in rare cases of spinal cord or traumatic brain injury
T	Test Clotting	▸ Check clotting regularly and target transfusion: ▸ Aim platelets > 100K/uL ▸ Aim INR & aPTT < 1.5 ▸ Aim fibrinogen > 2g/L
I	Imaging	▸ Consider: ▸ CT for most severely injured / haemodynamically unstable patients ▸ Select injuries from CT
C	Calcium	▸ Maintain ionised Ca^{2+} > 1.0 mmol/L ▸ Administer 10% Calcium Chloride over 10 mins as required

Algorithm 4.2: Causes of Coaguloathy in traumatic patients



Patients on anticoagulants and Anti-Platelet-Medication

Trauma patients who are therapeutically anticoagulated should have their anticoagulation reversed promptly. For emergency reversal of vitamin K-dependent oral anticoagulants, early use of prothrombin complex concentrate (PCC) is recommended. PCC can also help control life-threatening bleeding in patients treated with novel oral anticoagulants (NOACs). Idarucizumab (5 grams intravenously) is recommended for emergency reversal of dabigatran.

Patients taking anti-platelet medications are at high risk of severe bleeding after trauma. Platelet transfusion is the only way to reverse the effects of these drugs. Additionally, desmopressin (DDAVP) can be used at a dose of 0.4 micrograms per kilogram. It's important to inquire about the use of these medications when taking a patient's medical history.

Monitoring the shocked patient

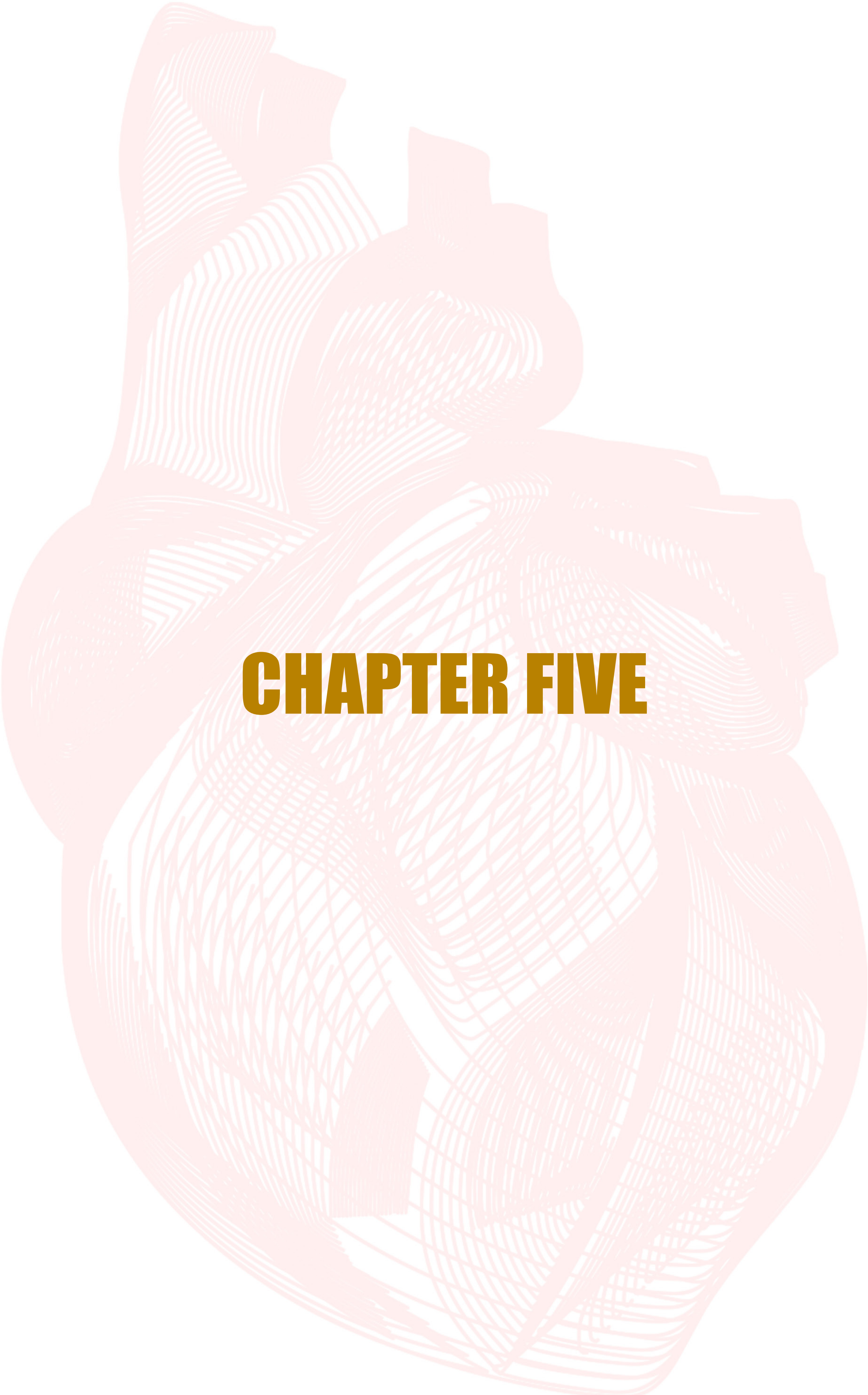
The overview provided above focuses on maintaining the function of vital organs while achieving hemostasis. However, patients are often complex and may not neatly fit into the described categories. Additionally, non-invasive vital sign measurements used initially become less accurate and reliable as the severity of shock worsens. This is especially true for non-invasive blood pressure and heart rate measurements. Therefore, early consideration should be given to using invasive arterial pressure monitoring in the resuscitation of patients with significant trauma. This allows for more precise and continuous monitoring of the patient's blood pressure and repeated blood sampling for markers of cellular oxygen deprivation, such as serum lactate, pH, and base excess.

Accurate measurement of urine output will require the insertion of a urinary catheter, with the volume recorded each time other vital signs are measured.

Monitoring the patient's core temperature is also important. Throughout the resuscitation process, efforts should be made to prevent heat loss by minimizing the patient's exposure to cold and using warmed intravenous fluids, patient covers, and active warming devices.

Completion of the primary survey

Upon completing the primary survey, the team leader must verify that all essential tasks are either finished or underway. At this point, results from an arterial blood gas analysis should be accessible. Metabolic acidosis often arises when tissues receive inadequate oxygen, causing anaerobic metabolism. The treatment includes early oxygen delivery through blood products, optimizing blood oxygen levels, and maintaining a normal body temperature. Patients with ongoing acidosis may require intubation and mechanical ventilation. Sodium bicarbonate is infrequently used, typically reserved for life-threatening cases of severe acidosis, assuming adequate perfusion and ventilation. Following the primary survey, the team should conduct a planning discussion and move to the secondary survey if no immediate interventions are necessary.



CHAPTER FIVE

Abdominal Trauma

Learning Objectives:

At the end of this chapter, the reader will be able to :

- Understand the common pathophysiologic conditions in abdominal trauma patients;
- Assess and manage the abdominal trauma.
- Identify the appropriate investigations for a patient with abdominal trauma.
- know how to perform a primary and secondary survey in an abdominal trauma patient
- Understand the role of surgery and interventional radiology in the management of patients with abdominal trauma.

Introduction

Abdominal injuries can be life-threatening and require careful management. Following trauma, the abdomen might harbor hidden bleeding that, unless promptly identified and managed, could result in direct outcomes.

In the initial 48 hours following an injury, the most prevalent causes of death among trauma patients are traumatic brain injury and significant bleeding. The latter is often due to direct abdominal trauma or damage at its periphery. Additionally, the prognosis of other unrelated injuries deteriorates in the presence of intra-abdominal bleeding, leading to poor perfusion, hypoxia, coagulopathy, and immunosuppression, all contributing to multi-organ system failure. Moreover, perforation of hollow organs with subsequent peritoneal contamination can lead to sepsis, which significantly contributes to delayed mortality post-abdominal trauma.

It is crucial for patients with abdominal trauma to receive swift assessment, stabilization, and timely surgical consultation to enhance the likelihood of a favorable outcome.

Mechanism of injury

Vehicular trauma is the predominant cause of blunt abdominal trauma among civilians. Collisions involving vehicles, both auto-to-auto and auto-to-pedestrian, account for 50-75% of these cases. Falls, along with industrial and recreational accidents, are also frequent causes.

Blunt abdominal injuries can be challenging to identify initially if there are no external trauma signs and no changes in vital signs. Significant blood loss may occur without noticeable changes in the abdomen's appearance. Blunt trauma can cause solid organ rupture and visceral damage, leading to hemorrhage, contamination from visceral contents, peritonitis, and related pelvic injuries. The spleen, liver, and small bowel are the organs most commonly affected.

Shearing injuries from improperly worn seat belts, a type of crush injury, may show a distinct seatbelt bruise pattern. Physical examination signs that should alert to a serious injury following blunt abdominal trauma include seat belt marks, rebound tenderness, hypotension with BP below 90, abdominal distension, guarding, and an accompanying femur fracture / pelvic fracture.

Blunt force trauma is usually spread across a broad area, except for localized impacts to the renal angle or anterior abdomen. Such trauma can cause abdominal damage due to deceleration or compression forces on solid organs like the spleen, liver, and kidneys, as well as on hollow organs such as the bowel or bladder.

Splenic rupture is the most common solid organ injury from blunt trauma, followed by liver lacerations. Bladder ruptures are also possible. While less frequent, intestinal injuries can certainly happen. Blunt trauma may cause diaphragmatic ruptures, particularly on the left side, with patients sometimes presenting vague symptoms weeks after the initial incident. Blunt aortic injuries, often from deceleration, can be fatal due to traumatic aortic transection at the accident scene. Survivors require careful blood pressure management and urgent surgery. Pelvic fractures, another frequent result of blunt abdominal trauma, can cause shearing of pelvic blood vessels, leading to retroperitoneal hemorrhage.

When injuries to the chest and pelvis are present, it's likely that there is also significant abdominal injury, considering the proximity of abdominal contents to the bony structures of the chest and pelvis. Also, signs of hypovolemia should prompt suspicion and investigation for abdominal injuries. In blunt trunk trauma, the abdomen should be presumed injured until proven otherwise.

Diagnosing abdominal trauma clinically is extremely challenging due to the unreliability of abdominal examinations. Signs of peritoneal irritation, such as tenderness and guarding, are often absent, especially when external injury signs are minimal, other injuries are distracting, or consciousness is impaired. Conversely, injuries to the chest or pelvis may mimic abdominal signs, leading to false positives. Thus, early imaging, particularly CT, has become integral to the initial assessment. In light of these factors, serial examinations by the same clinician can be valuable in patients not immediately requiring imaging.

Penetrating abdominal trauma

Penetrating injuries are often clear and severe. The small intestine, liver, and colon are the most frequently injured intra-abdominal organs. Only a third of these injuries will penetrate the peritoneum, and just half of those will necessitate surgical intervention. In contrast, 85% of abdominal gunshot wounds do penetrate the peritoneum, and 95% of these cases require surgery. If a penetrating object is impaled in a patient, it should not be removed outside of a surgical setting, as it may act as a tamponade; its removal could cause severe hemorrhage. Such removal should occur only in a controlled surgical environment equipped for intervention and resuscitation.

A patient in shock from an abdominal penetrating injury who does not respond to 1 liters of fluid resuscitation should be initiated with early blood transfusion, a chest X-ray and urgent surgical consult. The approach to hemodynamically stable patients with penetrating injuries to the lower chest or abdomen is variable. Surgeons concur that patients showing signs of peritonitis or hypovolemia require surgical exploration, but the treatment for stable patients without signs of peritonitis or sepsis is less definitive. Most stab wounds to the lower chest or abdomen ought to be examined promptly, as delays can lead to severe sepsis from hollow viscus perforation.

Some surgeons advocate for a selective approach in managing these patients. If the depth of the injury is uncertain, local wound exploration can determine if there is peritoneal penetration. Laparoscopy may become important in assessing penetrating injuries. All gunshot wounds to the lower chest and abdomen should be surgically explored, given a 90% chance of major intra abdominal structure damage.

Gunshot wounds typically result in small intestine and colonic injuries, while stab wounds more commonly affect the liver. Penetrating injuries can damage any abdominal organ and sometimes the chest, depending on the bullet or knife trajectory. Such thoraco-abdominal injuries may lead to traumatic arrest.

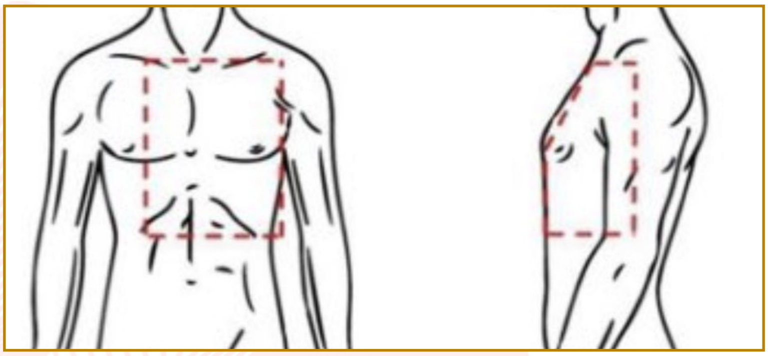


Figure 5.1 The boundaries of the abdomen. A-A: anterior axillary line, B-B: internipple line, C-C: inguinal ligament, D-D:

Assessment

The initial management of patients with abdominal trauma mirrors that of all trauma patients. Start with a swift primary survey, assessing the airway, breathing, circulation, disability, and exposure. If the abdomen is likely the source of significant hemorrhage, the patient should be taken to the operating room for an immediate laparotomy. Patients who are hemodynamically stable can undergo a more detailed evaluation as part of the secondary survey. This evaluation includes a thorough physical examination, including pelvic and rectal exams, and may necessitate specific laboratory and radiological tests.

The circulation team should assess the abdomen as a potential source of hemorrhage by asking:

- • Is there active bleeding?
- • Is the abdomen the probable location?
- • What methods can we employ to control the hemorrhage?

The abdomen should be considered as a potential source of hemorrhage if the injury mechanism suggests it, or if an abdominal examination reveals certain signs:

Focused Assessment with Sonography for Trauma (eFAST)

- • Abdominal bruising (seatbelt or tire marks);
- • Lacerations;
- • Scrotal or labial hematoma; flank hematoma;
- • Tenderness; guarding.

Additionally:

- • Shoulder-tip pain may indicate subphrenic irritation due to intraperitoneal blood;
- • The patient's back should also be examined; a log roll ought to be performed promptly, especially in cases of penetrating injuries.

A rectal examination may be necessary to identify the presence of rectal or anal blood, displaced pelvic bone fragments, anal sphincter tone, perianal sensation, and in males, prostate position. This examination can be performed supine or during a log roll.

A vaginal examination is warranted if there is perineal blood and the source is uncertain. In cases of evident blood loss from the vagina, the examination should be postponed until the patient is in the operating room. If an examination of the rectum and external genitalia does not indicate a urethral injury, a catheter should be inserted to measure urine output, relieve the bladder, and check for hematuria. A nasogastric tube is beneficial for stomach decompression, as most patients experience some level of gastroparesis following trauma.

Intra-abdominal hemorrhage should be considered uncontrollable and necessitates urgent surgical evaluation. Patients who are hemodynamically unstable require immediate surgical intervention, which may preclude the completion of the primary survey due to the urgency of surgery. Meanwhile, controlled resuscitation using blood products and tranexamic acid should begin in accordance with the local major hemorrhage protocol, alongside measures to prevent hypothermia.

For patients without an immediate need for laparotomy but with a high suspicion of internal bleeding, early CT scanning is advised. This may also serve as a preliminary step to interventional radiology. In more sophisticated trauma systems, it is feasible to conduct resuscitation and a CT scan concurrently, allowing rapid access to hemorrhage control surgery.

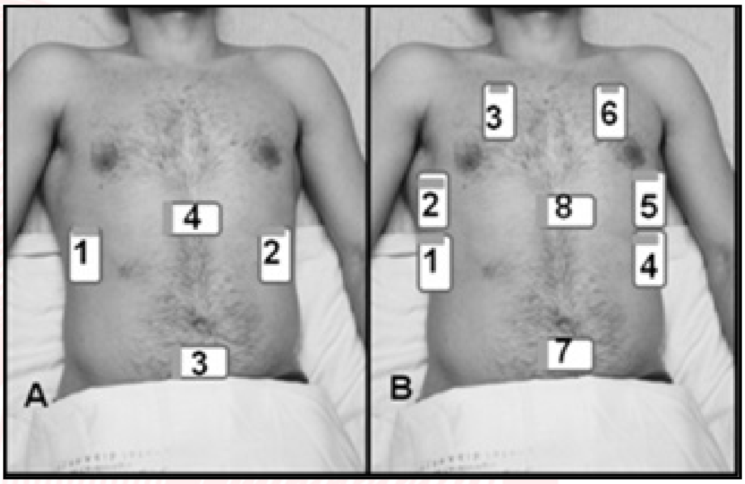
Investigations

Initial laboratory evaluation should include hemoglobin, hematocrit, and platelet count to establish a baseline. Blood typing and screening are also necessary in case a transfusion of packed red cells is required. An elevated lactate level is an excellent indicator of shock. Base deficit is another indicator of shock. The role of amylase in abdominal trauma is uncertain. The presence of gross hematuria in the urine examination may suggest significant injury to the urogenital tract.

In addition to routine blood tests, various other diagnostic procedures are available, which should be utilized according to local expertise and protocols include:

Focused Assessment with Sonography in Trauma (eFAST)

A positive abdominal eFAST in a trauma patient is indicated by a dark, anechoic strip in the peritoneal areas, suggesting hemoperitoneum. However, FAST is not reliable for identifying the source of the fluid and may overlook injuries to visceral organs, particularly in solid organs without capsular rupture and retroperitoneal injuries. Thus, it is more useful as a 'rule-in' rather than a 'rule-out' test for free intra-abdominal fluid.



FAST - Focused Assessment with Sonography for Trauma;
EFAST - Extended Focused Assessment with Sonography for Trauma.

Figure 5.2 - FAST (A) and EFAST (B) anatomical references.

The five views employed in FAST are:

- Subxiphoid transverse view: to assess for pericardial effusion and injuries to the left lobe of the liver
- Longitudinal view of the right upper quadrant: to evaluate injuries to the right liver, right kidney, and Morison's pouch
- Longitudinal view of the left upper quadrant: to check for splenic and left kidney injuries
- Transverse and longitudinal views of the suprapubic region: to examine the bladder and the pouch of Douglas.

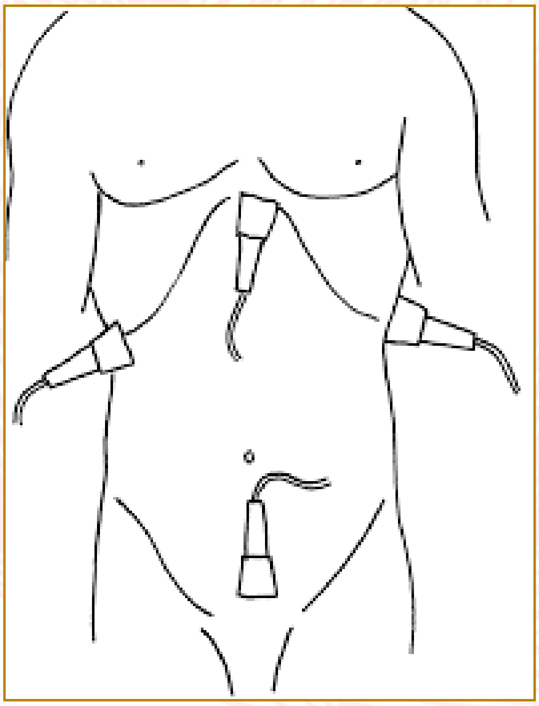


Figure 5.3 FAST Views

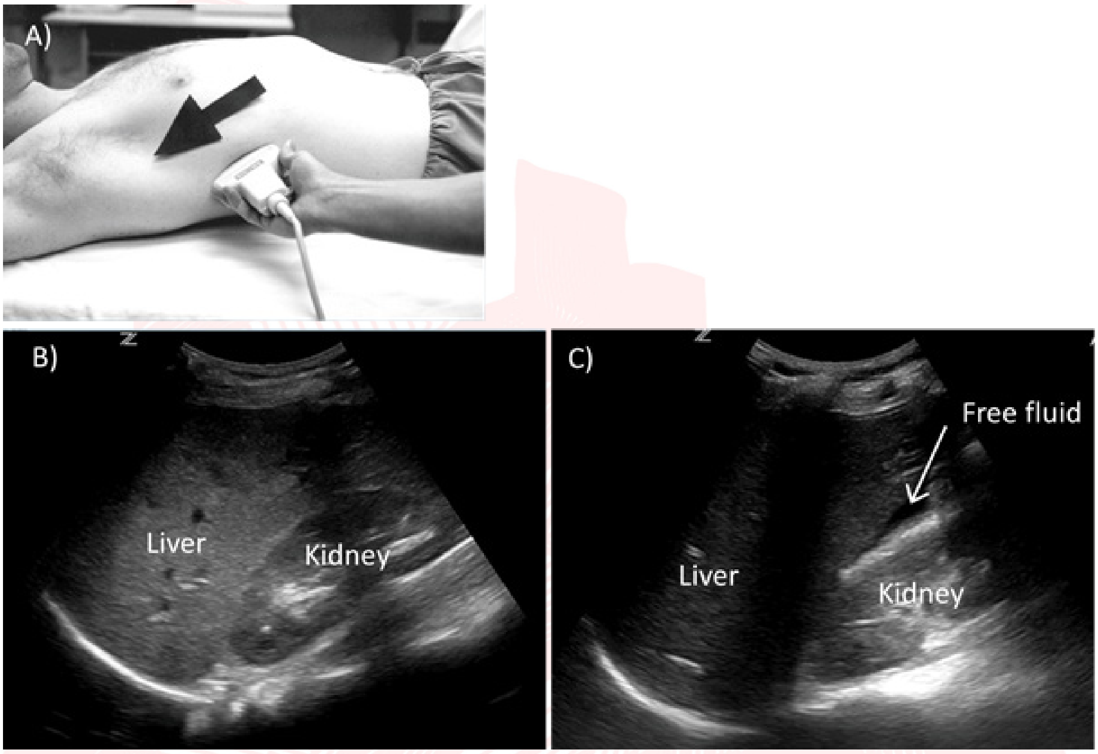


Figure 5.4 Right Flank View. A) Probe positioning. B) Normal view. C) Positive view with free fluid.

CT Scanning

CT scanning enables the imaging of both visceral and musculoskeletal structures, rendering it highly suitable for most abdominal trauma cases. It has replaced many traditional investigations, such as intravenous urography for renal trauma. However, its reliability is lower for detecting injuries to the diaphragm, bowel, or pancreas. Clinical judgment about the necessity for surgical intervention is crucial when interpreting CT findings and can override a negative CT result. In such cases, the input of a senior, experienced surgeon is vital.

Plain X-rays

A chest x-ray might be performed if there's uncertainty about the existence or location of a pneumothorax. It can also detect lower rib fractures or signs of diaphragmatic injury, although subphrenic gas may not be visible on a supine film. Plain abdominal x-rays are seldom needed but can be used to locate residual foreign objects like bullets or shrapnel.

Diagnostic peritoneal lavage

Diagnostic peritoneal lavage has become nearly obsolete in clinical practice due to the advent of sonography and the increased availability of early CT scans. Its use is now limited to scenarios where other imaging options are unavailable. Although it is sensitive to hemoperitoneum, it lacks specificity compared to sonography.

Method	Time/Cost	Advantage/Disadvantage
Physical examination	Quick/no cost	Useful for serial examinations, very limited by other injuries, coma, drug intoxication, poor sensitivity and specificity
iagnostic peritoneal lavage (DPL)	Quick/inexpensive	Rapid results in unstable patients but invasive and may be overly sensitive for blood and not specific for the site of injury, requires experience and may be limited if previous surgery
Focused assessment with sonography for trauma (FAST)	Quick/inexpensive	Rapid detection of intra-abdominal fluid and pericardial tamponade, may be limited by operator experience, large body habits, subcutaneous air, poor for detection of bowel injury. Fairly sensitive but not highly specific
Helical computerized abdominal tomography (CT)	Slower/expensive	Most specific for the site of injury and can evaluate retroperitoneum, very good sensitivity but may miss bowel injury, risk of reaction to contrast dye

Table 5.1 Comparison of diagnostic methods for abdominal trauma

Emergent Interventions

In immediate management, while some hypotensive patients may respond to fluid resuscitation, prompt intervention is imperative when a patient in shock exhibits a positive FAST scan or fails to respond adequately to treatment, and the injury mechanism indicates intraperitoneal hemorrhage. It's vital to recognize that resuscitation might necessitate laparotomy and that stabilizing hypovolemia could be unachievable before surgically managing the hemorrhage. However, in critically compromised patients, initiating damage control resuscitation prior to surgery is essential; as opening the abdominal wall may lead to significant hypotension by eliminating the tamponade effect.

Damage control surgery is a type of operative intervention typically performed on patients in shock due to abdominal trauma. It involves three phases:

Phase 1: Abbreviated laparotomy for haemorrhage and contamination control

The primary goal is to identify and manage life-threatening haemorrhage. Essential vessels are repaired, organs that can be spared, such as the spleen, are removed, vital organs are packed, intestinal perforations are stapled, and bleeding from other sources is controlled with packing and haemostatic agents. The abdomen is then closed using a 'Bogota Bag' or left open (laparostomy) to prevent intra-abdominal compartment syndrome. If available, an interventional radiologist may employ an endovascular approach to locate and control arterial bleeding through temporary or permanent embolization, leading to complete haemostasis or reducing bleeding to allow for limited surgical intervention.

Phase 2: Intensive Care Unit Resuscitation

The objective here is to optimize tissue oxygenation and address the 'lethal triad' of acidosis, coagulopathy, and hypothermia. Interventional radiology may be utilized again, if suitable, to minimize blood loss prior to further surgical procedures.

Phase 3: Second Look or Definitive Surgery

The goal at this stage is to perform corrective and restorative surgery on a patient who is normothermic, not acidotic or coagulopathic, and is receiving proper nutrition. If the abdomen is open, the process of closure begins, although it may necessitate more than one operation.

Interventional Radiology (Angiography and Embolization)

It is increasingly acknowledged that many intra-abdominal injuries that cause hemorrhage can be treated with angiography and embolization, either as standalone treatments or in combination with surgery.

Advantages: minimally invasive; precise localization of arterial bleeding; ability to control bleeding through embolization.

Disadvantages:Competencies may not be available in all trauma-receiving centers; the process can be time-consuming (1–5 hours depending on complexity); technically challenging in cases of obesity, hypotension, degloving injuries, or atherosclerotic disease; reported complications include hematoma, thrombosis, subintimal dissection, and pseudoaneurysm; exposure to radiation; adverse reactions to contrast material.

Table 5.2 Comparison of management of the trauma patient

Site of Trauma	Non-operative	Interventional Radiology	Damage Control Surgery
Abdominal aorta	No role	Occlusion balloon, stent graft for suitable lesions	Injury requiring visceral revascularization or untreatable by endovascular aneurysm repair
Kidney	Subcapsular or retroperitoneal hematoma without active arterial bleeding	Active arterial bleeding: embolisation or stent graft	Renal injury in association with multiple other bleeding sites or other injuries requiring urgent surgical repair
Spleen	Lacerations, hematoma without active bleeding or evidence of false aneurysm	Active arterial bleeding or false aneurysm: • Focal embolisation for local lesion • Proximal embolisation for diffuse injury	Packing or splenectomy for active bleeding in association with multiple other bleeding sites
Liver	Subcapsular or intraperitoneal hematoma or lacerations without active arterial bleeding	Active arterial bleeding: • Focal embolisation if possible • Non-selective embolisation if multiple bleeding sites as long as portal vein is patent	Renal injury in association with multiple other bleeding sites or other injuries requiring urgent surgical repair
elvis	Minor injury with no active bleeding	Focal embolisation for arterial injury (bleeding, false aneurysm, or cut-off)	External fixation and subsequent packing if bleeding from veins or bones
ntestine	Focal contusion with no evidence of ischemia, perforation, or hemorrhage	Focal bleeding with no evidence of ischemia or perforation. Or, to stabilize patient, allowing interval laparotomy pending treatment of other injuries	Ischemia or perforation requiring laparotomy ± bowel resection

Blood Transfusion

Warmed blood products are the preferred fluids for resuscitating unstable hypovolemic trauma patients. Typically, stored blood is processed into various products to ensure the most suitable is administered. Understanding local blood product availability is crucial as practices vary by country. For instance, fibrinogen concentrate is accessible in some European nations, and the use of clotting factor concentrates in trauma is on the rise.

Initially, to replenish haemoglobin levels, patients are given packed red blood cells (PRBCs), which lack clotting factors and platelets. Ideally, blood transfusions should be preceded by a full crossmatch to confirm compatibility, but this process can take up to an hour. In emergencies, the administration of uncrossmatched O-negative blood may be necessary. As soon as possible, type-specific blood should replace it, ensuring ABO and Rhesus compatibility between recipient and donor.

In cases of ongoing bleeding or significant blood loss, red cells must be supplemented with fresh frozen plasma (FFP), clotting factor concentrates, cryoprecipitate, and platelets are optimally utilized by adhering to a major hemorrhage protocol (MHP). The implementation of MHP is pivotal in the fluid resuscitation of patients compromised physiologically by blood loss or those with active bleeding. In certain regions, blood products are also accessible in pre-hospital settings.

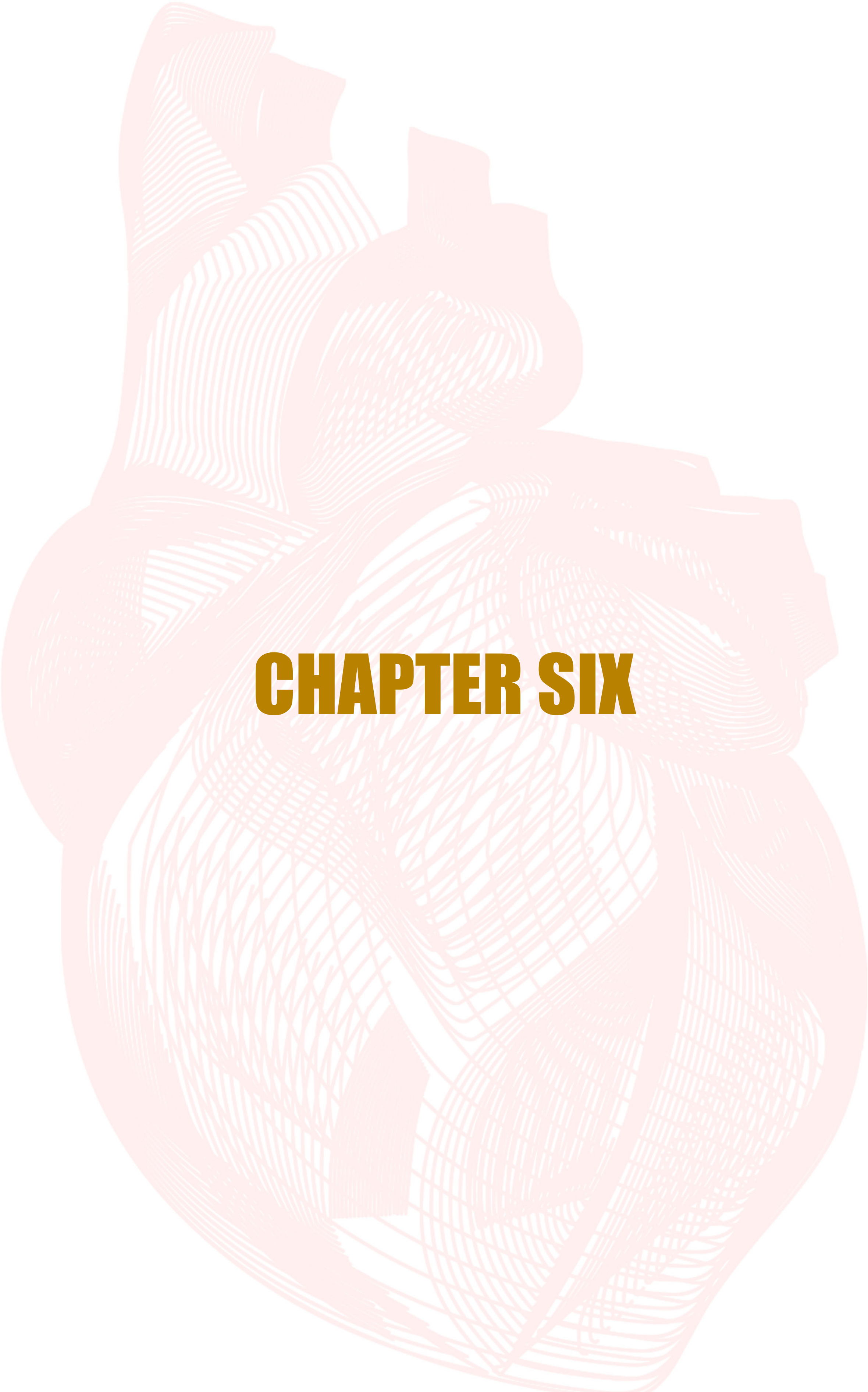
To prevent iatrogenic hypothermia, all fluids must be warmed prior to administration. This is effectively done by keeping crystalloids in a warming cabinet and using a warming device to minimize heat loss as the fluid travels through the infusion set. For the resuscitation of severely shocked patients, the availability of rapid infusion devices capable of delivering large volumes of warmed blood products or fluids is essential.

Secondary Survey:

Once the patient is hemodynamically stable and the primary survey is complete, the abdomen should be reassessed as part of the secondary survey.

Patients with a high suspicion of intra-abdominal trauma, yet without a specific focus identified, should undergo serial physical examinations, repeated blood tests, and abdominal sonography. Trauma to the diaphragm, pancreas, duodenum, and small bowel may be overlooked during the initial assessment and might necessitate further CT scans or surgical exploration.

Should the secondary survey indicate signs of an acute abdomen, an urgent surgical consultation is necessary.



CHAPTER SIX

Pelvic Trauma

Learning Objectives:

At the end of this chapter, the reader will be able to:

- Assess and manage the pelvic trauma.
- Select and interpret the appropriate investigations and imaging for a patient with pelvic injuries.
- Know how to perform a primary and secondary survey in a trauma patient with pelvic injuries.
- Understand the role of surgery and imaging in the management of patients with pelvic injuries.

Introduction

Pelvic trauma is a potentially life-threatening injury often resulting from high-energy impacts. However, pelvic fractures may also occur from low-energy events, such as falls from a standing position, particularly in elderly patients with osteoporotic bones. Consequently, pelvic fractures present a bimodal distribution among patients, with younger individuals typically suffering more severe injuries. The complexity of the vasculature and organs within the pelvis means that severe injuries causing pelvic disruption can lead to significant hemorrhage and organ damage, with mortality rates ranging from 6-35%, and potentially over 50% if the injury is open.

As such, pelvic ring fractures require systematic and timely management to minimize mortality rates. This necessitates critical treatment decisions both in the trauma bay and the operating room. This chapter focuses on pelvic ring injuries resulting from high-energy trauma rather than low-energy trauma in the elderly. Nonetheless, the principles discussed should also be considered for patients with low-energy injuries, as they can still experience significant hemorrhage and pelvic instability. It is important to distinguish pelvic ring fractures from acetabular fractures; while pelvic ring fractures may include an acetabular component, an isolated acetabular fracture does not constitute pelvic disruption.

Important Anatomic Considerations

Bone

The pelvic ring is composed of three bones: the sacrum and two innominate bones. Each innominate bone is formed by the fusion of the ilium, ischium, and pubis. If this rigid ring-like structure breaks at one point, it is likely to break at another, potentially leading to pelvic instability. There are also multiple processes for the origin and insertion of muscles and ligaments.

BONES OF THE PELVIC GIRDLE

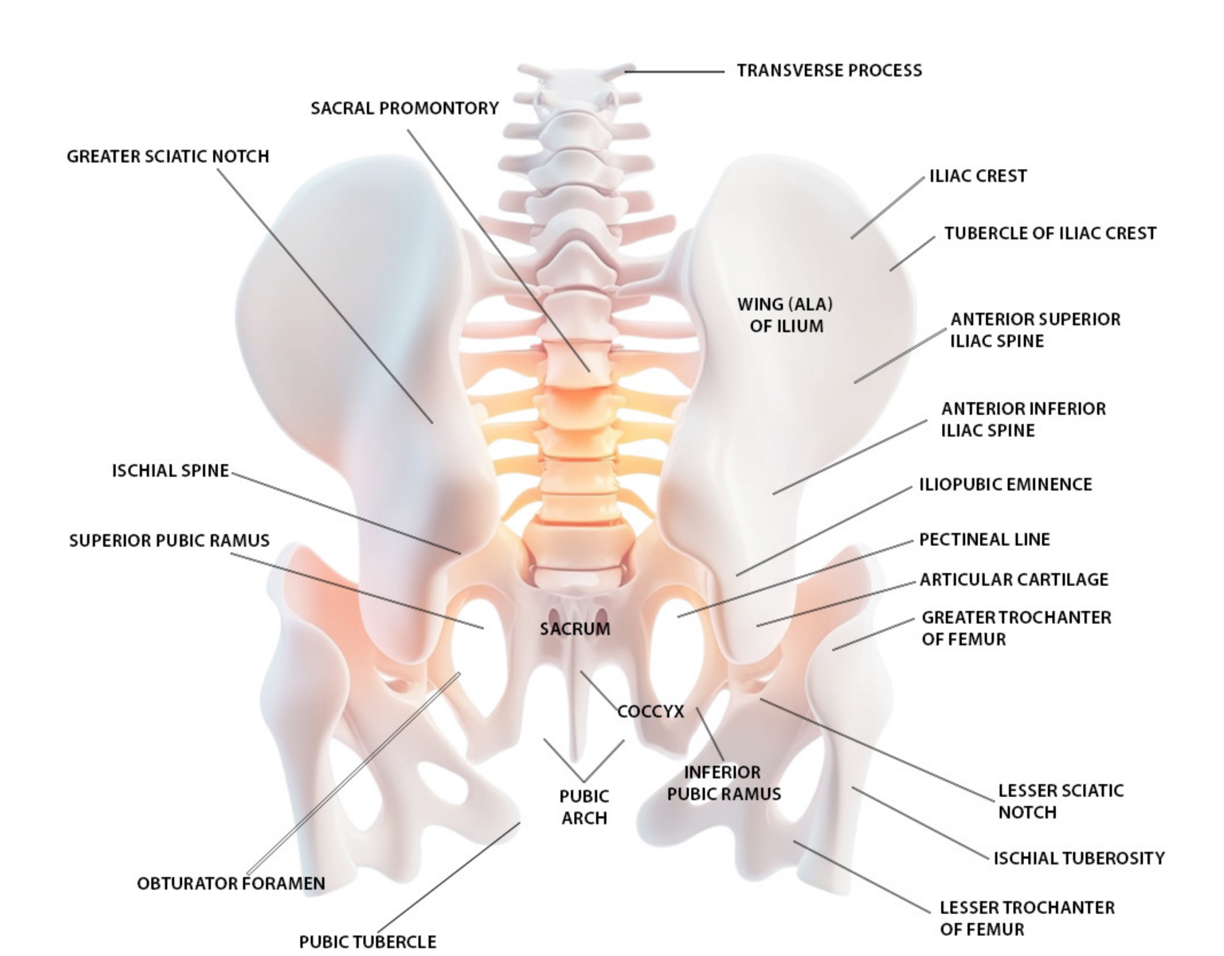


Figure 6.1 Anatomy of the pelvic girdle bones

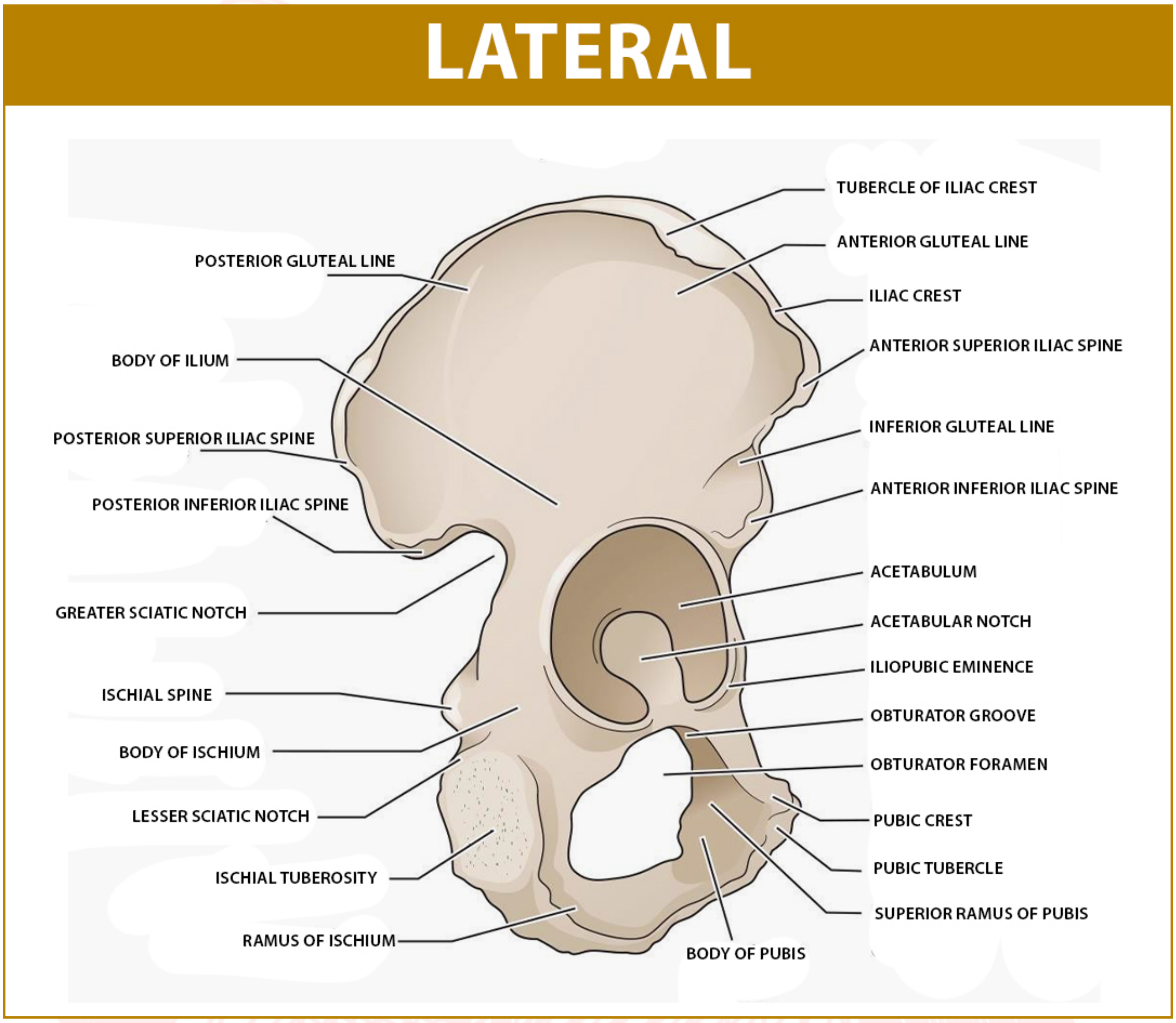


Figure 6.2 Ligaments

Pelvic stability relies on the function of ligaments, as there is no inherent bony stability. Additionally, pelvic instability can occur due to the rupture of ligaments even in the absence of a bony fracture.

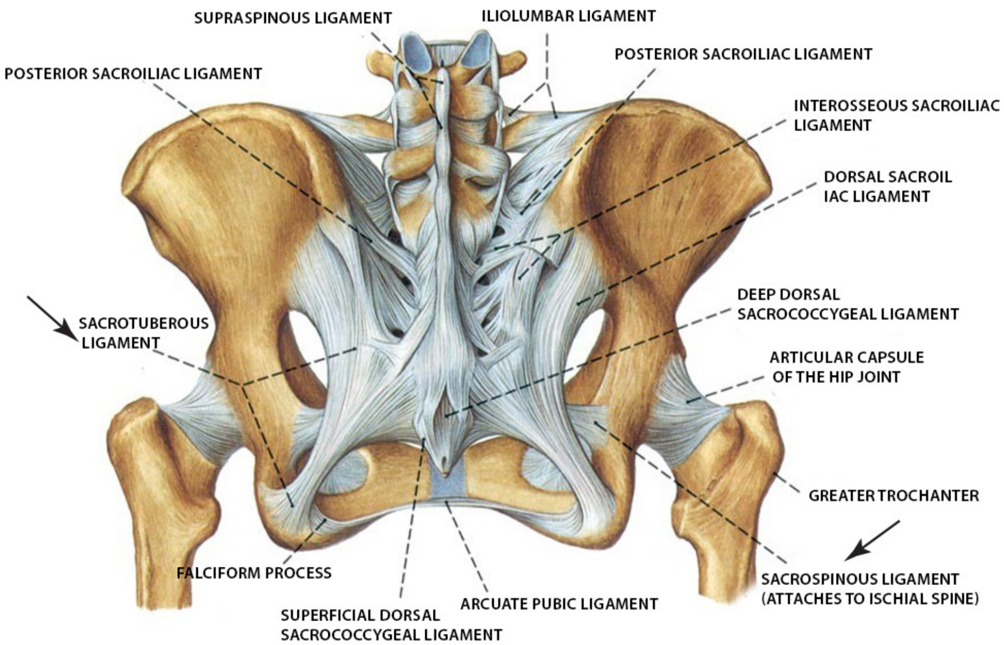
- Transversely placed ligaments resist rotational forces

1. Short posterior SI
2. Iliolumbar
3. Anterior SI
4. Sacrospinous

- Vertically placed ligaments resist vertical shear or vertical migration

1. Long posterior SI
2. Lateral lumbosacral
3. Sacrotuberous

PELVIS AND LIGAMENTS, REAR VIEW, FEMALE



PELVIS AND LIGAMENTS FRONT VIEW FROM ABOVE, MALE

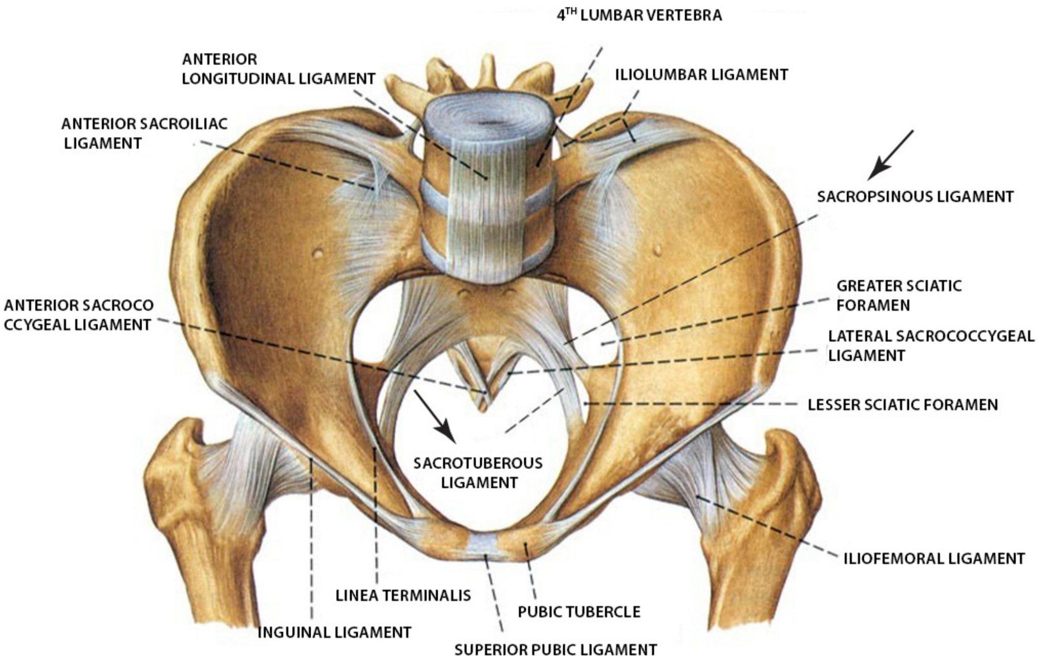


Figure 6.3 Pelvis ligament's structure

Vasculature

Abdominal aorta normally bifurcates around L4 into the common iliac arteries which again bifurcates shortly after into the external and internal iliac arteries. The external iliac artery traverses the iliac fossa, just superior to the pelvic brim, and proceeds beneath the inguinal ligament to transition into the common femoral artery.

The internal iliac artery splits into a posterior division, giving rise to the superior gluteal artery, and an anterior division, which forms the obturator artery. Corona mortis is the anastomotic connection between the obturator and femoral artery posterior to the superior pubic rami

The inferior vena cava is formed at the level of approximately L5 by the confluence of the common iliac veins, which themselves are formed by the union of the external and internal iliac veins.

- External iliac vein is formed from the femoral veins and courses with the external iliac artery through the pelvis
- Internal iliac vein drains the important sacral venous plexus that lies just anterior to the sacrum

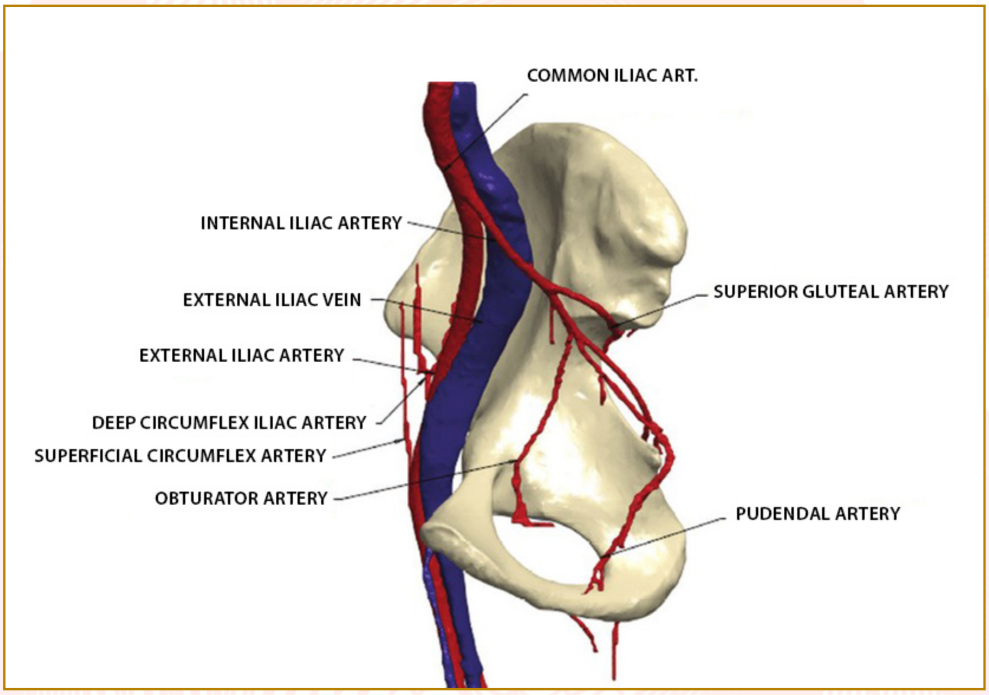


Figure 6.4 pelvis vascular structure

Neurologic

Femoral and sacral plexus courses from nerve roots around and through pelvis as it transitions into peripheral nerves

- Lower lumbar and sacral nerve roots
  - Lumbosacral trunk, which consist mainly of the L5 nerve root travels across sacral ala 2cm medial to SI joint
- Peripheral nerves
  - Femoral nerve crosses iliac fossa and passes underneath inguinal ligament
  - Obturator nerve travels around pelvic brim and through obturator foramen
  - Lateral femoral cutaneous nerve (LFCN) crosses iliac fossa superior to femoral nerve and usually

passes underneath inguinal ligament just medial to ASIS

- Sciatic nerve passes through greater sciatic foramen and posterior to acetabulum and femoral head
- Superior and inferior gluteal nerves pass through greater sciatic foramen and into the gluteal musculature

Etiology & Mechanisms of Injury

Causes of pelvic fractures typically consists of high-energy blunt trauma

- Motor vehicle collision: 20-66%
- Pedestrian vs. Automobile: 14-59%
- Motorcycle: 5-9%
- Falls
- Crush

All disruptions of the pelvic ring can be attributed to three distinct mechanisms of injury or a complex interplay among them.

- Anterior-posterior force
    - "Open book" injuries result from an anteriorly directed force and are highly likely to cause hemorrhage. This is because such a mechanism increases the volume of the pelvis, leading to more bleeding before the tamponade effect occurs. A diastasis of the pubic symphysis by 3 cm can result in the pelvis volume doubling from its normal size.

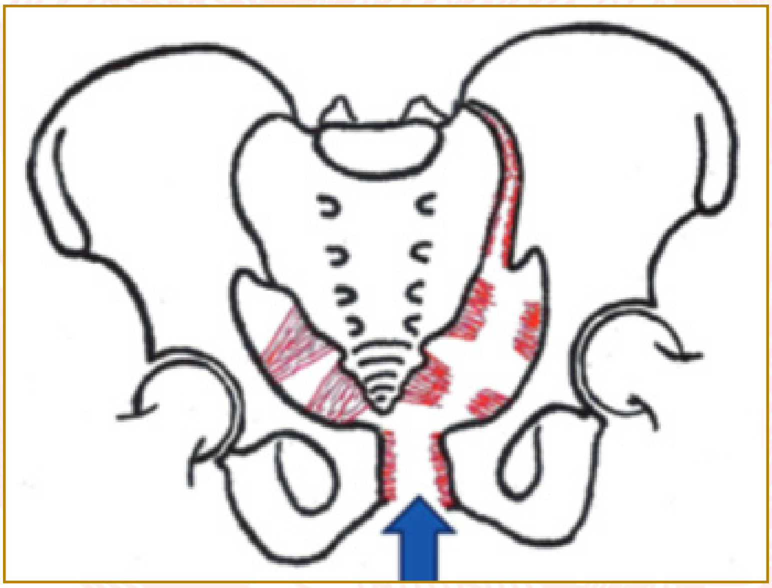
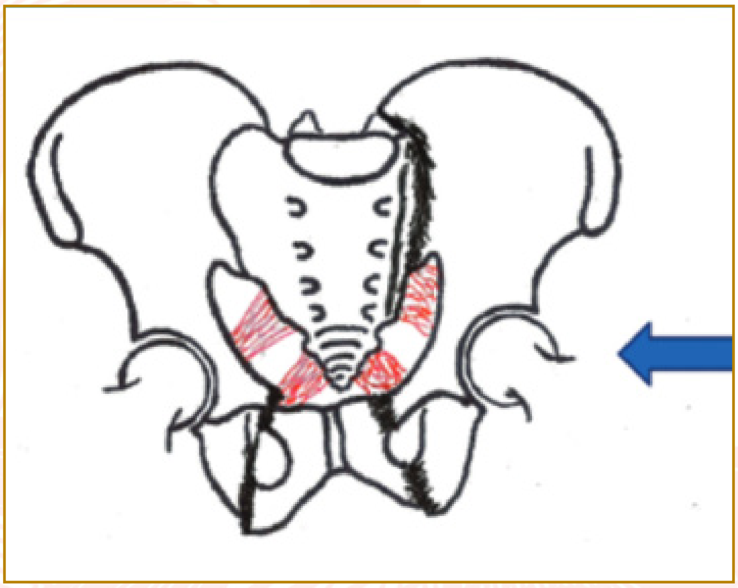


Figure 6.5 X-ray and diagrammatic interpretation of open book type fracture

- Lateral compression force
    - Crush injuries resulting from a lateral force typically present a lower risk of hemorrhage due to the associated decrease in pelvic volume.



- Vertical shear
    - Vertical displacement of the hemipelvis is typically due to a fall from a height. It is the most unstable type of injury and can also increase the volume of the pelvis. There is a significantly higher likelihood of neurological injury associated with this condition.

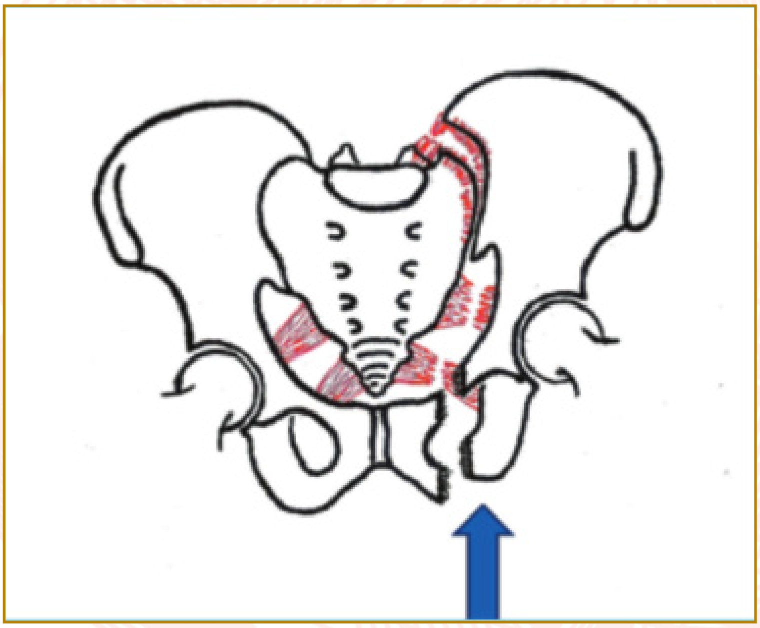


Figure 6.7 X-ray and diagrammatic representation of vertical shear injury

Associated Injuries

Systemic

The forces required to disrupt the pelvic ring are substantial, often resulting in a high incidence of concurrent systemic injuries. This underscores the significance of adhering to ATLS principles, which ensure a systematic and swift assessment and management of trauma patients. Consequently, a pelvic fracture should never be viewed in isolation.

- Head injuries – 40%
- Spine fractures – 25%
- Chest injuries – 63%
- Long bone fractures – 50%
- Abdominal injuries – 40%
- Other fractures – 70%

Local

The close proximity of various organs to the pelvis means that a pelvic fracture often results in local injury to adjacent structures. Therefore, it is crucial to assess each organ system for potential injuries whenever a pelvic fracture occurs.

Vascular

Significant pelvic hemorrhage may be seen in up to 75% of patients, and 15-30% of those with high-energy pelvic fractures may become hemodynamically unstable. Major pelvic hemorrhage can occur swiftly because the normal retroperitoneal space is able to hold up to 4 liters of blood before venous tamponade takes place.

Sources of bleeding

- Venous – responsible for 80-90% of pelvic hemorrhage
  - Most common: posterior sacral and pelvic venous plexuses
  - Less common: Femoral and iliac veins

- Arterial – responsible for 10-20%
  - Most common: Internal pudendal (27%), superior gluteal (25%), and lateral sacral (23%) arteries
  - Less common: Obturator (16%), inferior gluteal (6%), femoral, and iliac arteries
- Cancellous bone
  - Typically, does not cause hemodynamic instability although can still bleed a significant amount

Neurological

Neurological injuries may affect about 10-20% of patients with pelvic disruptions, manifesting as damage to either the nerve roots or the peripheral nerves. Therefore, a thorough examination of the lower extremities is essential.

- Lower lumbar and sacral nerve roots (~65%)
    - Most likely to injure L5 or S1 nerve roots
    - Can also injure the roots of the cauda equina
    - Most common with Zone 3 and transverse sacral fractures (see classification section)
- Peripheral nerves (~35%)
    - Superior gluteal and obturator nerves more liable to be injured
- Iatrogenic injuries
    - also can occur in the setting of SI screws and external fixators
    - LFCN and L5 nerve root are the most common

Skin

Open pelvic fractures are observed in approximately 2-4% of cases, commonly presenting with lacerations to the perineum and groin. Morel-Lavallée lesions, which involve the shearing of the dermis from the fascia, are also associated with pelvic fractures, necessitating a comprehensive examination for diagnosis.

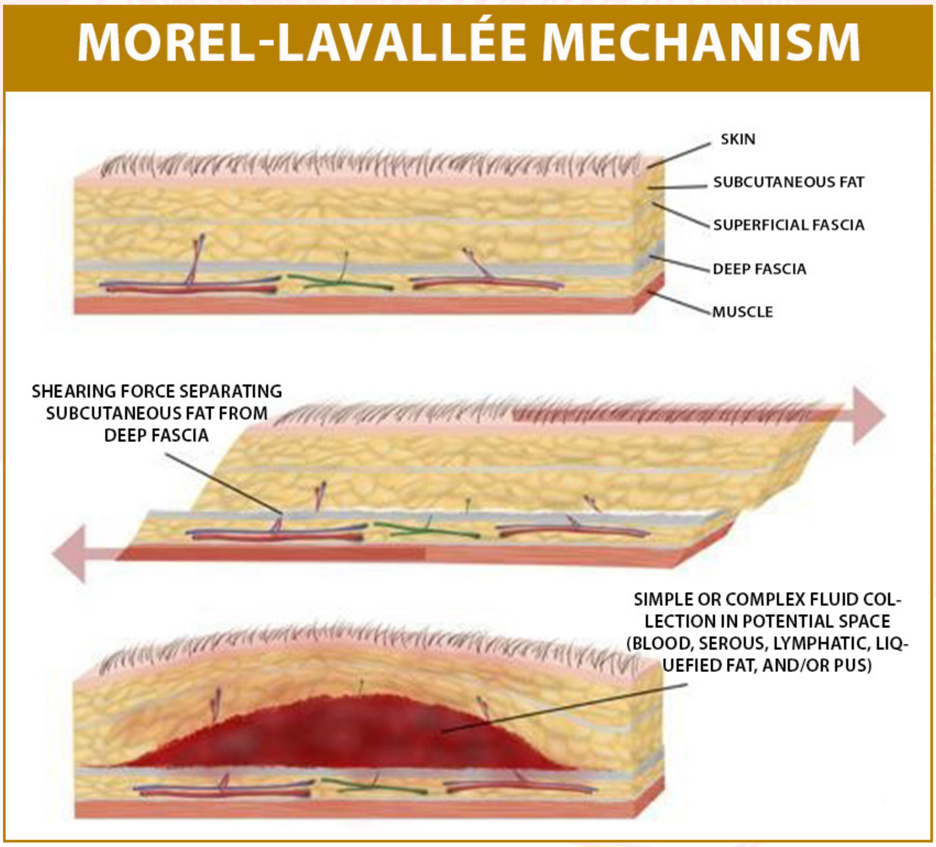


Figure 6.8 Morel- Lavallee mechanism

Rectal

An open fracture is classified as such when there is a laceration to the rectum. Approximately 25% of open pelvic fractures involve a laceration to the rectum, and this is more commonly associated with penetrating pelvic trauma than with blunt trauma.

Genitourinary

Can occur in up to 12-20% of patients with pelvic trauma

Urological

- Ureter, bladder, or urethra injuries
- Posterior urethral tear is the most common associated injury, stretch injury is more common than laceration
- More common in males than females

Can lead to sexual dysfunction in up to 50% of patients with injury
Theoretical risk of bladder injury with overtightening of pelvic binder application in lateral compression type pelvis fracture

Vaginal

Along with rectal injury, vaginal laceration also classifies as an open fracture, Previous study found vaginal lacerations in approximately 4% of pelvis fractures

Classification

Pelvis fractures can most simply be classified based on location

- Pubic rami – superior or inferior
- Pubic root
- Acetabulum – separate classification system (Judet & Letournel)
- Iliac wing: Crescent fracture – unstable iliac wing fracture that enters SI joint
- Sacrum fractures

Denis classification: Zone 1 – fracture lateral to foramina; Zone 2 – fracture through foramina; Zone 3 – fracture medial to foramina into spinal canal, can also have transverse fractures with varying vertical components that are highly unstable.

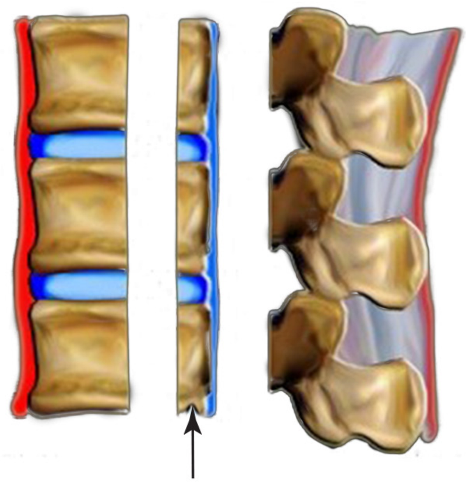


Figure 6.9 Denis classification

other main classification systems exist for pelvic ring disruptions: Young-Burgess Classification which organizes pelvic fractures into the three mechanisms of injury discussed earlier:

Anterior-posterior compression (APC)

- I = Symphysis widening of < 2.5 cm (disruption of pubic symphyseal ligaments only)
- II = Symphysis widening of > 2.5 cm with SI joint widening anteriorly only (pattern I with disruption of sacrotuberous, sacrospinous, and anterior SI ligaments as well)
- III = Symphysis widening and SI joint widening anteriorly and posteriorly (pattern II with disruption of posterior SI ligaments as well)

Lateral compression (LC)

- I = Pubic rami fracture(s) and ipsilateral sacral ala compression fracture
- II = Pubic rami fracture(s), ipsilateral sacral ala compression fracture and ipsilateral crescent fracture (SI fracture dislocation)
- III = Ipsilateral LC II with contralateral APC II or III (windswept pelvis)

Vertical Shear (VS)

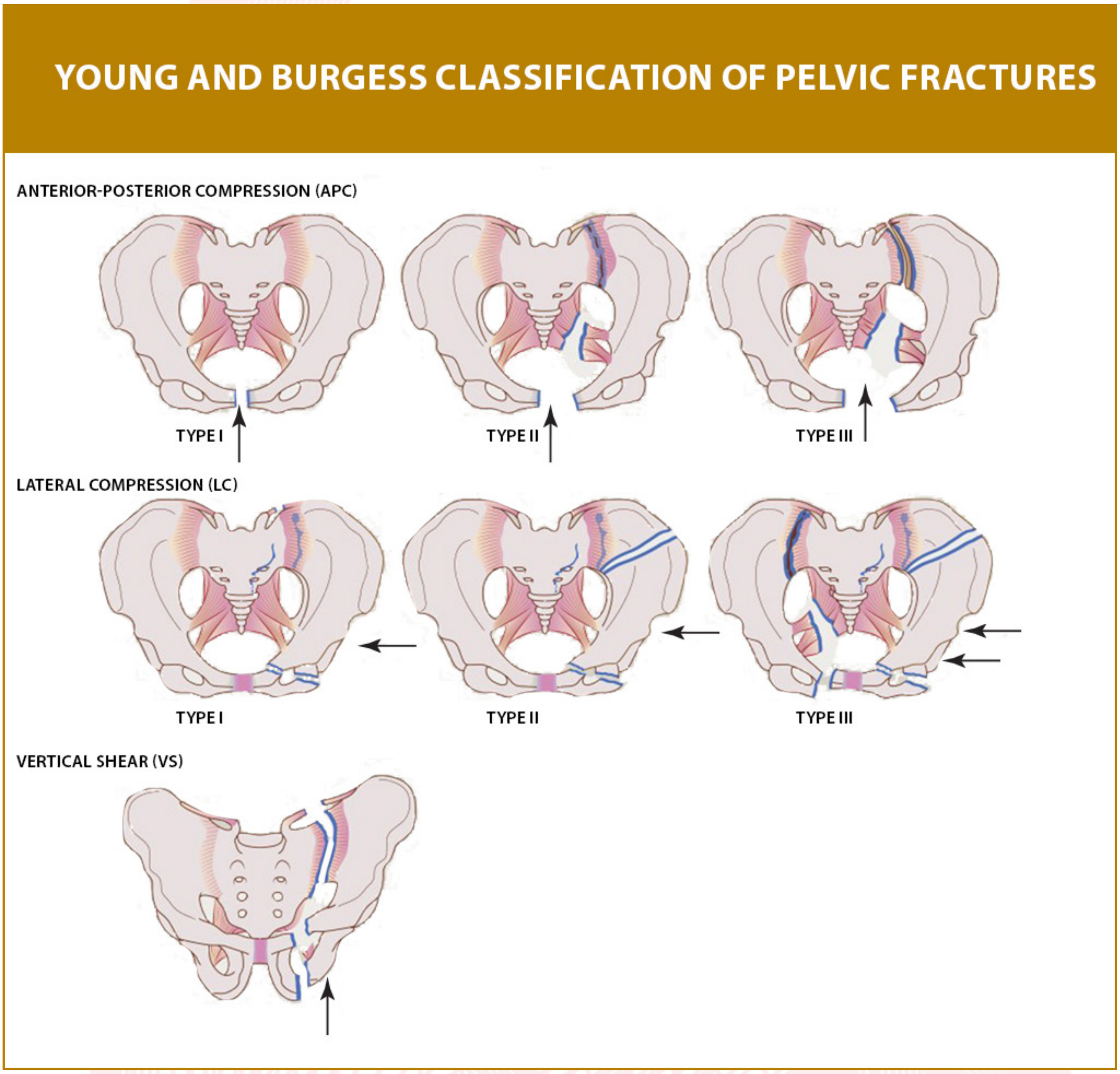


Figure 6.10 Young and Burgess classification of pelvic fractures

Evaluation & Initial Management

Primary Survey

In the primary survey, the protocol outlined in chapter 1 is followed, with team members executing their roles concurrently. Circulation personnel must specifically search for signs of actual or potential pelvic injury. While clear indicators may be present, if they are not, the diagnosis might initially rely on the injury's mechanism and signs of hypovolemia when no other cause is evident. In cases where a trauma or orthopedic surgeon is not an initial member of the trauma team, involving one at the earliest opportunity is crucial, as part of the clinical examination must be conducted by a specialist to determine the stability of the injury and to differentiate between rotational and vertically unstable pelvic ring injuries.

Clinical Examination

In the clinical examination of pelvic fractures, it is crucial to assess potential lesions to soft tissues and internal organs both outside and inside the pelvic ring. This includes checking for skin lacerations around the iliac crests, degloving injuries (Morelle-Lavallée lesions) at the greater trochanter, upper thigh, or the lumbosacral junction.

Special attention is required for the perineal region; a large hematoma in the scrotum or labia may indirectly indicate a pelvic floor lesion. The presence of spontaneous blood at the external urethral meatus could suggest a lesion in the lower urogenital tract, such as a bladder rupture or urethral tear.

Additionally, skin lacerations around the anus or vagina, or impalement injuries, could be sources of significant bleeding and contamination. Patients who have experienced high-energy trauma should undergo a thorough examination of the perineum and genitalia, including a rectal examination, with all findings documented. If a vaginal injury is suspected, such as blood observed emanating from the vagina, a vaginal examination is warranted, typically conducted in the operating room.

Pelvic examination should be conducted by a member of the circulatory staff who is trained and able to interpret the results. Initially, the examiner should position themselves next to the patient lying supine, at the pelvic level. Rocking or springing the pelvis to check for instability is not advised as it may exacerbate bleeding by disturbing any initial clot formation. A gentle palpation for tenderness can be done over the iliac crests and pubis. This evaluation should be carried out only once.

The second stage of the pelvic examination must be conducted by a trained trauma or orthopedic surgeon. This is normally only performed in the hemodynamically stable patient. In the correct hands it gives additional information that will aid surgical planning. It has no role in the hyper-acute situation.

The examiner stands beside the lower leg of the supine patient. One hand is used to lift the patient's leg carefully off the table, while the other hand is placed on the ipsilateral iliac crest to control movement. When the examiner can pull down or up one hemipelvis while the opposite hemipelvis does not move nor rotate, a vertical instability exists. A vertical instability never exists without rotational instability. With two simple tests, the examiner is able to differentiate between different forms of pelvic ring lesions, which correspond with different severities of trauma.

Figure 6.11 Pelvic examination

Imaging

If a CT scan is not immediately available as part of the primary survey, an antero-posterior x-ray of the pelvis is mandatory for every polytrauma patient. This will immediately detect any significant disruptions and displacements. However, analyzing the posterior hemipelvis is challenging, and fractures or dislocations may be missed due to overlying soft tissue, bowel contents, and intrapelvic hematoma.

CT imaging is essential for a definitive diagnosis. High-speed CT scanners perform total body multislice CT with contrast in hemodynamically stable or compensated patients. If the CT is near the Emergency Department and resuscitation is ongoing, this examination can be done right away, eliminating the need for conventional x-rays.

Management of pelvic ring disruptions, which result from high-energy transfer, must be considered potentially life-threatening due to the immediate risk of hemorrhage. The hemorrhage can originate from three primary sources: the large bone fragments of the dorsal pelvic ring, the multiple small vessels of the plexus anterior to the sacrum and around the organs of the small pelvis, and arterial bleeding within and around the small pelvis. Notably, active arterial bleeding occurs in less than 10% of pelvic trauma cases.

The initial management focuses on the patient's hemodynamic status rather than fracture stabilization, adhering to the standard approach outlined in chapter 1. Various methods, which are complementary rather than competitive, are available to reduce or control blood loss through indirect or direct mechanisms.

Figure 6.12 Pelvic immobilization

Pelvic immobilization is achieved using a pelvic binder or sheet, which operates on the same principle. When wrapped around the pelvic ring, they exert direct pressure on the disrupted elements, decrease the volume of the small pelvis, and prevent large movements during manipulation or transport. An additional benefit of a pelvic binder is that it keeps the pelvic and abdominal regions unobstructed and accessible for further interventions. If a pelvic binder is not available on-site, a sheet can be utilized as an alternative.

Figure 6.13 Pelvic immobilization application

A pelvic binder should be applied immediately when an unstable pelvic ring with hypotension is suspected, either before transport or upon hospital arrival. Imaging is not necessary for immobilization in these cases. The binder can remain for several hours but must only be removed by a resuscitation team due to the risk of recurrent bleeding and hypovolemia.

Careful application is crucial; the fractured pelvic ring should be minimally displaced. The binder remains in place until the risk of pelvic hemorrhage is mitigated and should be removed after consulting the relevant specialist, ideally within 6 hours and no later than 24 hours post-injury.

If a CT scan rules out an unstable, hemorrhagic pelvic ring fracture, the binder may be removed in the resuscitation room with the trauma team present. A pelvic radiograph should be taken post-removal in all cases.

Urinary Catheter:

A single, careful attempt at urinary catheterization by an experienced physician is allowed, even if clinical or CT findings indicate a potential urethral or bladder injury. It is essential to document the procedure and note whether the urine is clear or blood-tinged. The observation of blood-tinged urine necessitates conducting a retrograde urethrogram through the catheter. Should the catheter fail to pass, or if it passes but only blood is drained, do not inflate the balloon. Instead, remove the catheter and proceed with a retrograde urethrogram.

Detecting a urethral or bladder injury requires immediate notification of the on-call urologist. If catheterization is unsuccessful, a suprapubic catheter must be placed, either percutaneously in the resuscitation area or via an open approach in the operating room. The insertion of a suprapubic catheter may influence the schedule of any pelvic surgery; therefore, the pelvic team should be consulted early in the process.

Subsequent Management

Interventions listed below are typically conducted after the patient has been transferred out of the Emergency Department. However, the decision to proceed with these interventions should be made as promptly as possible, based on clinical assessments and the patient's response to initial resuscitation efforts. The trauma team leader should determine the most suitable intervention for the patient to facilitate further treatment planning.

Pelvic Clamp

This is a surgical procedure that should only be performed by trained professionals. The apparatus comprises two substantial K-wires and a sizable C-shaped clamp. Its purpose is to re-establish the stability of the dorsal hemipelvis, and its use is integral to the resuscitation of patients in extremis or those with marginal hemodynamics. members of the trauma team should be well-acquainted with the indications for its deployment and how to apply it.

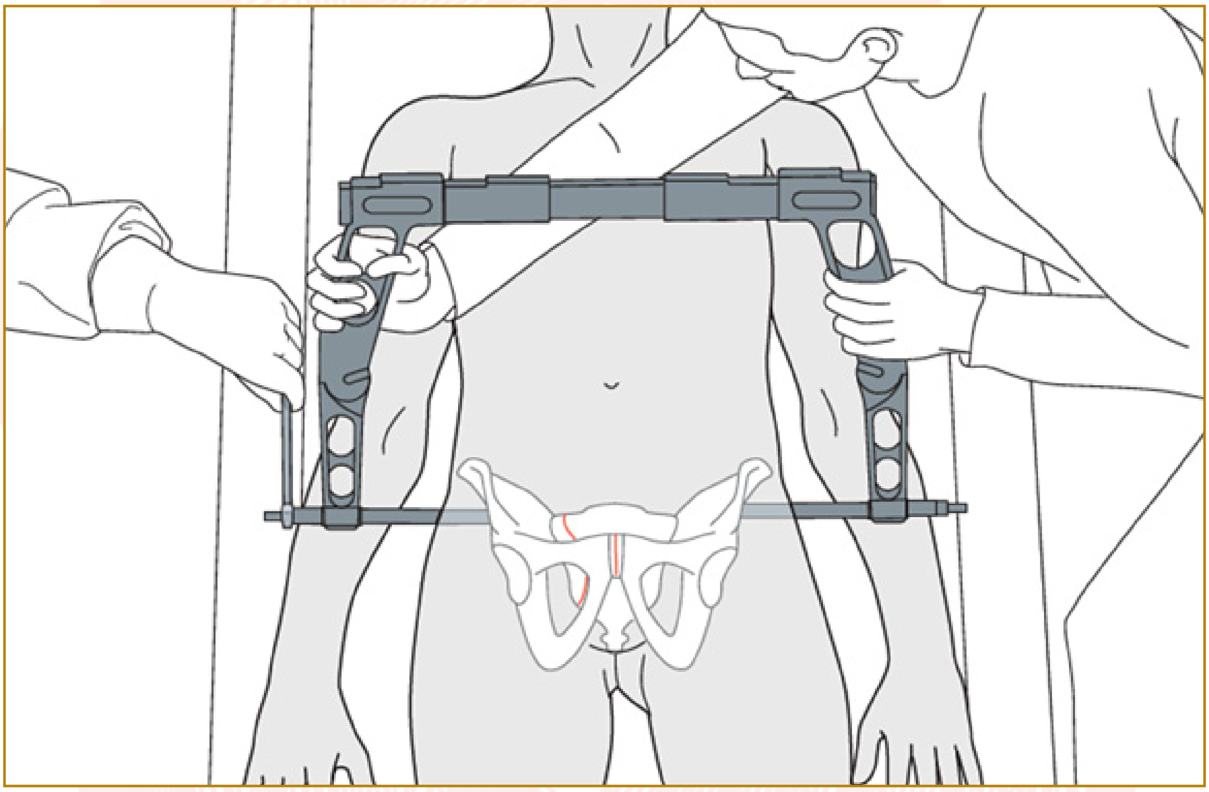


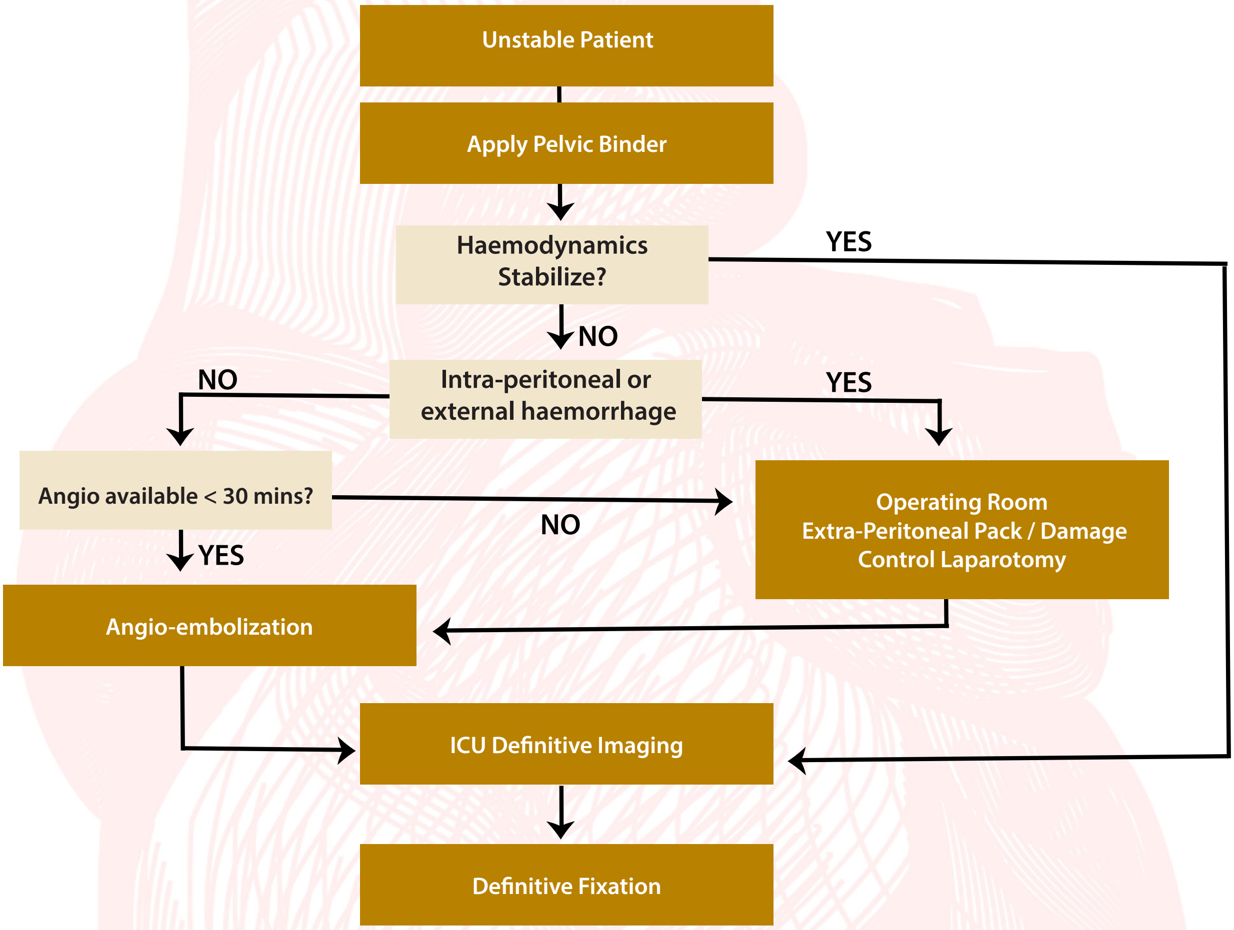
Figure 6.13 Pelvic Clamp

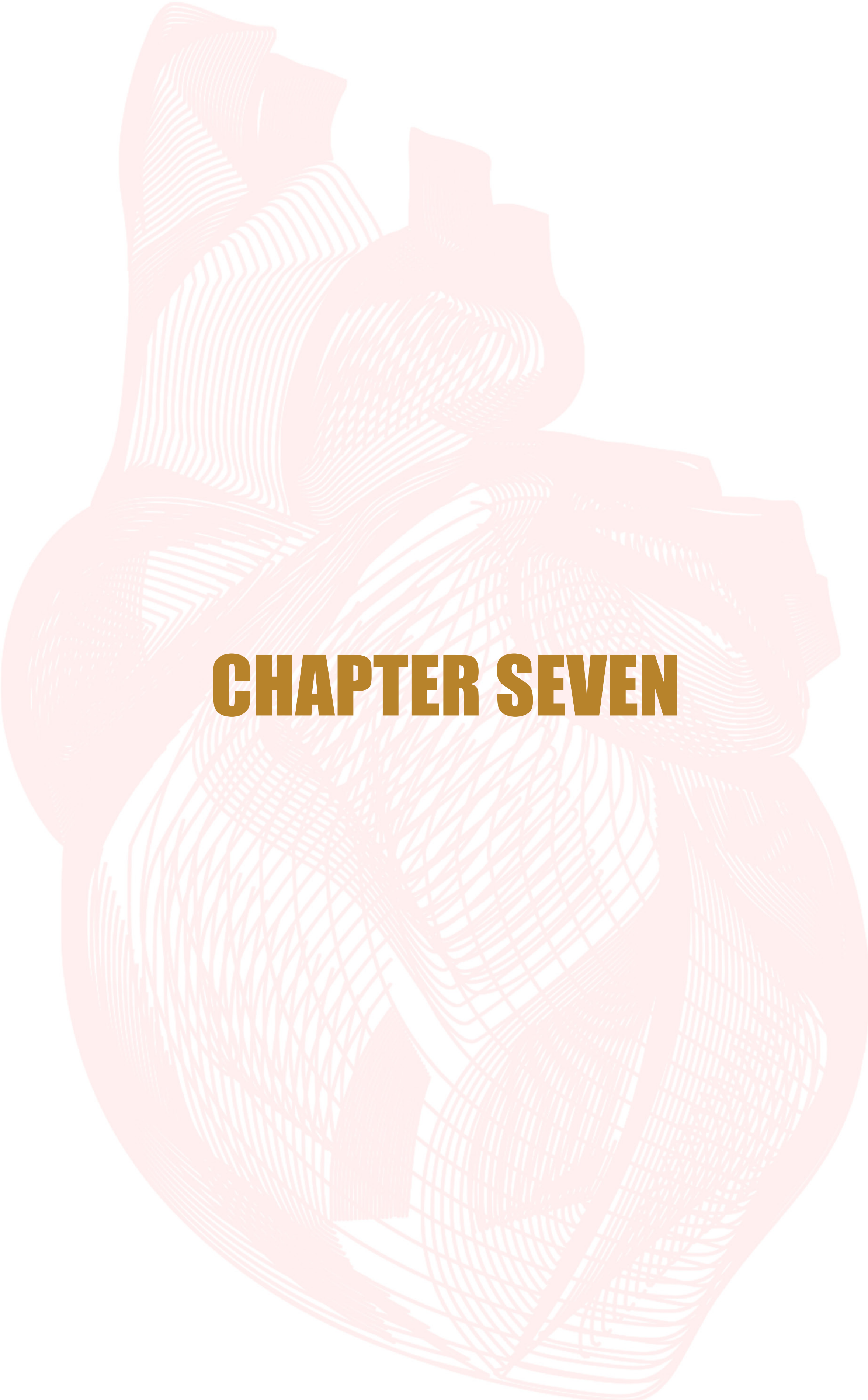
External fixators are used for provisional management in resuscitated patients until definitive reduction and fixation can be achieved. They are most suitable for patients who are or become hemodynamically stable with resuscitation.

Surgical packing is employed for transient responders who continue to bleed after pelvic clamping or external fixation and require more aggressive management. It is crucial to understand that surgical packing is ineffective and hazardous if pelvic clamping or external fixation has not been performed, as the lack of bone fragment stabilization will exacerbate blood loss.

Selective angiography and embolization are increasingly utilized in the management of bleeding pelvic fractures. This intervention is indicated when a CT scan with contrast reveals a blush signifying ongoing arterial bleeding, when a patient needs continuous transfusion exceeding 0.5 units of blood per hour, or when patients experience repeated hypotension episodes despite resuscitation. It is often employed following pelvic packing if there is still evidence of a persistent small arterial bleed. However, due to its time-consuming nature, it is not recommended in cases of active bleeding from large vessels.

Algorithm 6.1 Pelvic Fracture management algorithm





CHAPTER SEVEN

Head Trauma

Learning Objectives:

At the end of this chapter, the reader will be able to :

- Assess and manage the head trauma.
- Select the appropriate investigations and imaging for a patient with pelvic injuries.
- Know how to perform a primary and secondary survey in a trauma patient with head injuries.
- Understand the role of neurosurgery in the management of head injuries.

Introduction

In Europe, the rate of moderate to severe head injuries is estimated at 200 to 300 cases per 100,000 individuals. These injuries most commonly happen during leisure activities (35%), in domestic settings (30%), and in the workplace (15%). About 28% of those affected are below 15 years of age, and there's an increasing trend among individuals over 65, particularly those on anticoagulant medications. Alcohol is involved in 25% of these incidents, while road traffic accidents make up 26%.

The majority of head injury patients initially receive care at non-specialist facilities, with more than half requiring transfer to a neurosurgical center. Trauma system implementation could reduce the necessity for secondary transfers by ensuring patients with urgent brain injuries are taken directly to a Major Trauma Center (MTC) from the incident site.

The prognosis following a severe head injury is often grim, with a mortality rate of 31%, 3% entering a vegetative state, 16% becoming severely disabled, and 20% moderately disabled. Only 30% achieve a good recovery six months after the injury. Given that head injuries are most prevalent among young males, the economic and social repercussions of delayed or inadequate treatment are profound.

Traumatic brain injury (TBI)

Traumatic brain injury (TBI) is an impairment of brain function resulting from external force. As a dynamic process, all injuries and symptoms, no matter how minor they appear initially, must be taken seriously due to the potential for rapid progression to life-threatening states.

Primary Injury:

Occurs from the forces at the event's moment:

- Scalp disruption (laceration)
- Bone (cranial vault, skull base, facial bones)
- Vasculature (SDH, EDH, IPH, IVH)
- Brain parenchyma (Contusion, DAI)

Secondary Injury:

Develops after the initial impact and can be more insidious and challenging to manage (due to autoregulation failure/loss of normal hemostasis):

- Hypoxemia
- Cerebral edema
- Ischemia
- Increased ICP
- Initial hyperemia
- Seizures

Pathophysiology:

The intracranial volume, approximately 1500 ml, is the sum of its components:

- Brain (85-90% of volume)
- Blood (10%)
- Cerebrospinal fluid (<3%)

Monro-Kellie Doctrine:

The brain resides within the skull's rigid and inelastic confines. The intracranial compartment can tolerate minor volume increases before pressure rises. Significant head injuries lead to cerebral edema, increasing the brain's relative volume. Without compensatory measures, such as reducing the volume of another intracranial component, pressure within this compartment escalates. The brain's compliance is minimal, and it cannot withstand substantial volume increases from diffuse cerebral edema or significant mass lesions like a hematoma.

Cerebral Perfusion Pressure (CPP):

CPP = MAP – ICP

CPP represents the net pressure that facilitates blood delivery to the brain. Typically, cerebral blood flow (CBF) remains stable when the mean arterial pressure (MAP) ranges between 50-150 mmHg.

Pressure-Passive Flow:

If MAP drops below 50 mm Hg or exceeds 150 mm Hg, arterioles lose their autoregulatory ability, making blood flow solely dependent on blood pressure. This autoregulation is compromised in traumatic brain injury (TBI), rendering CBF variable and directly proportional to CPP. Consequently, a MAP below 50 mmHg endangers the brain with ischemia due to inadequate blood flow, while a MAP above 160 mmHg leads to excessive CBF, culminating in elevated intracranial pressure (ICP). Hence, pressure-passive flow occurs in and around areas affected by injury.

Secondary brain injury arises from complications with the patient's airway, breathing, and circulation, which are the critical areas to address when assessing and managing a head injury. Even brief periods of hypoxia and hypotension, less than five minutes, can significantly worsen outcomes; thus, prevention is crucial. Secondary brain injury may also stem from delayed diagnosis, delayed definitive treatment, or inadequate management of other injuries.

The factors contributing to secondary brain injury often exacerbate each other, leading to further decline. Adhering to the primary survey priorities for all trauma patients can mitigate this progression.

Assessment:

The management of traumatic brain injury is centered on stabilizing the patient and preventing secondary neuronal damage to minimize further neuronal loss. The optimal approach involves ensuring adequate oxygenation and maintaining blood pressure to achieve sufficient brain perfusion. Brain injury assessment relies on the evaluation of the Glasgow Coma Scale (GCS) and the examination of pupil reactivity. A GCS score below 9 signifies a severe brain injury.

Classification of TBI:

Mild: GCS 14-15. The patient is awake, typically without focal deficits.

Moderate: GCS 9-13. There is an altered level of consciousness, and focal deficits may be present.

Severe: GCS < 9. Patients generally fulfill the criteria for being comatose.

Assessment and management

Traumatic Brain Injury (TBI) can be classified into two main types: closed head injury and penetrating head injury. This classification is not solely based on the mechanism of injury, as the treatment for these two types of TBI can vary. Clinical presentations of TBI patients range widely, from those who are ambulatory and report a sports-related head injury to those who are critically injured and transported by helicopter after a high-speed vehicle collision.

The Glasgow Coma Scale (GCS), created by Jennett and Teasdale, assesses the overall consciousness level in TBI patients and helps categorize the severity of head injuries. The GCS comprises three components: eye opening (E), motor response (M), and verbal response (V). The total GCS score is the sum of these three components, with the highest possible score being 15 and the lowest being 3, calculated as follows:

Table 7.1 GCS

Glasgow Coma Scale	
Eye opening:	
Spontaneously	4
To speech	3
To pain	2
None	1
Motor response:	
Obeys commands	6
Localises to pain	5
Flexion (withdraws) to pain	4
Abnormal flexion to pain (decorticate)	3
Extension to pain (decerebrate)	2
None	1
Verbal response:	
Orientated	5
Confused	4
Inappropriate words	3
Incomprehensible sounds	2
None	1

Pupillary Examination:

Critical part of the evaluation of patients with TBI, especially in patients with severe injuries.

Table 7.2 Pupillary Examination

Pupil size	Light response	Interpretation
Unilaterally dilated	Sluggish or fixed	CN III nerve compression secondary to tentorial herniation
Bilaterally dilated	Sluggish or fixed	Inadequate brain perfusion, Bilateral CN III palsy
Unilaterally dilated or equal	Cross-reactive (Marcus-Gu nn)	Optic nerve injury
Bilaterally constricted	May be difficult to determine	Drugs (opiates), Metabolic encephalopathy, Pontine lesion
Unilaterally constricted	Preserved	Injured sympathetic pathway, e.g., Carotid sheath injury

The following should also be noted in the assessment:

- Check ears and nose for bleeding and/or CSF leakage.
- Check for signs of basilar skull fracture.
- Full neurologic exam including cranial nerves, strength, tone and reflexes. Associated injuries

Airway

Personnel responsible for airway, breathing, and circulation must identify and address any immediate life-threatening conditions, which may be extracranial even in the presence of significant head injuries. Resuscitation should be conducted on a tilting trolley so that, if appropriate, a 15-degree head-up tilt can be applied to lower intracranial pressure (ICP), provided that blood pressure remains stable.

For airway and cervical spine control: ensure continuous oxygenation; maintain verbal communication with the patient whenever possible; monitor and inform the team leader of any changes in communication with the patient; and, where necessary, carry out tracheal intubation and mechanical ventilation control .

Attempting tracheal intubation can exacerbate secondary brain injury if not done carefully, due to the risks of hypoxia and hypertension, which can increase intracranial pressure. Additionally, the cervical spinal cord is at risk of injury.

The likelihood of a cervical spine injury in an unconscious patient after a road traffic accident or fall ranges from 5-10%. Tracheal intubation can be challenging due to the limited mouth opening from a semi-rigid collar, making laryngoscopy more difficult. Manual in-line stabilization (MILS) is the preferred method to maintain spinal stability; once MILS is applied, the collar should be opened to aid intubation, necessitating an extra person to sustain MILS.

After successful intubation, it's crucial to reapply immobilization of the cervical spine properly. The collar must fit well, and the head should be kept in a neutral position. Incorrect collar tightness or poor head positioning can increase intracranial pressure (ICP) due to venous congestion.when urgent surgical treatment is anticipated, early tracheal intubation should be performed.

Indications for intubation and ventilation following a head injury

- Inability to maintain an adequate airway
- Risk Of aspiration from loss of laryngeal reflexes
- Inadequate ventilation:
- Hypoxia: Pao2 <9kPa (70mmHg) breathing air

  Pa02<13kPa (100mmHg) breathing oxygen

- Hypercarbia: PaC02>6kPa (45mmHg)
- To assist in acute reduction of ICPby hyperventilation
- Spontaneous hyperventilation causing Paco <3.5kPa
- Rapidly deteriorating GCSregardless of initial level
- Initial GCS<9
- Continuous or recurrent seizures

Breathing

The respiratory pattern and rate of a spontaneously breathing patient provide crucial information and must be continuously monitored. The best assessment of ventilation adequacy comes from arterial blood gas (ABG) analysis. Thoracic injuries need to be quickly identified, and appropriate measures taken to ensure sufficient oxygenation; this may involve mechanical ventilation and the application of positive end-expiratory pressure (PEEP).

For such patients, neuromuscular blocking agents and proper sedation are necessary to prevent them from struggling against the ventilator; expert assistance is crucial. Ventilators should be adjusted to minimize intrathoracic pressure as high pressures can hinder venous return from the brain and increase intracranial pressure (ICP). Ventilation adequacy should be regularly evaluated through ABG analysis.

If ventilation is insufficient, it must be augmented. Hypercapnia is a significant cause of elevated ICP and must be avoided.

After achieving intubation, the initial goal should be normoventilation ($PaCO_2$, 35-40 mmHg), but it's important to note that end-tidal CO_2 ($etCO_2$) is typically at least 4 mm Hg lower than $PaCO_2$. Hyperventilation can lower intracranial pressure by causing cerebral arterioles to constrict, thus reducing the volume of arterial blood in the brain.

However, if it's excessive ($PaCO_2$ <30 mmHg), it can significantly decrease blood flow to already compromised areas, exacerbating ischemia and potentially worsening any injury. Hyperventilation is usually reserved for patients at risk of imminent herniation and should be done after consulting a neurosurgeon or with intensive monitoring in a neurosurgical unit. Accurate control of the ventilation degree necessitates regular arterial blood gas monitoring.

Circulation

A closed intracranial injury never causes hypovolemic shock in an adult patient. Children under 18 months with open fontanelles, or adults with significant scalp injuries, may lose enough blood to cause shock. However, other life-threatening injuries should always be considered and ruled out.

For patients with head injuries, aim for a mean arterial pressure greater than 90 mmHg (SBP > 110 mmHg) to maintain a cerebral perfusion pressure between 50-70 mmHg and prevent cerebral hypoperfusion and ischemia.

Patients not in shock:

In normotensive patients, intravenous fluid should be limited to maintenance volumes of isotonic solutions, such as 0.9% saline or compound sodium lactate. Isolated hypertension should not be treated initially, as it represents the body's effort to maintain cerebral perfusion despite increased intracranial pressure.

Patients in shock:

Intravenous fluids should be administered to restore blood pressure to an appropriate level for the patient until hemorrhage is controlled . Afterward, aim for a mean arterial pressure greater than 90 mmHg to avoid the detrimental effects of hypotension on cerebral perfusion. Initially, a bolus of warmed isotonic crystalloid or colloid is given according to local protocols, with the type of fluid adjusted based on the patient's response.

Accurate recording of all fluids administered is crucial; early monitoring of circulatory status (e.g., central venous pressure) should be considered to guide fluid management.

In cases of head trauma, glucose-containing fluids (such as 5% glucose or 4% glucose with 0.18% saline) are avoided because they:

- Lower plasma sodium, thus reducing plasma osmolality and worsening cerebral edema;
- Lead to hyperglycemia, which is associated with poorer neurological outcomes.
-

Hypertonic solutions are saline solutions, such as 7.5%. While no advantage has been shown over isotonic solutions in extracranial trauma patients, they seem to aid in the resuscitation of traumatic brain injury patients. This could be due to:

- Rapid administration of smaller volumes to replenish circulating volume and cerebral perfusion;
- Reduction in cerebral edema and intracranial pressure; modulation of the inflammatory response, which helps minimize further neuronal damage.

Typically administered as a bolus, it's important to note that repeated use may lead to hyperchloremic acidosis. The role of mannitol will be addressed subsequently.

Disability (neurological assessment)

Both hypoxia and hypotension can contribute to decreased consciousness. After addressing these issues, a neurological status assessment should be conducted, evaluating:

- Glasgow Coma Scale ;
- Pupillary size, symmetry, and response to light;
- Variance in motor response between the left and right sides.

A unilateral brain injury may lead to differing responses between a patient's left and right sides, often manifesting as unilateral weakness, asymmetrical motor responses, or variations in pupillary size and light reaction. These symptoms are indicative of a focal brain injury. For instance, an extradural (epidural) hematoma can cause an ipsilateral dilated, unresponsive pupil and contralateral motor function decline.

In alert patients, the upper-arm drift test is a sensitive indicator of partial hemiplegia. The patient is instructed to extend their arms forward with their eyes closed and palms up. An arm rotating to a palm-down position is an early and sensitive indicator of concern.

Convulsions can occur spontaneously in epilepsy patients or may signal primary or secondary brain damage. Untreated convulsions can lead to further brain damage due to potential hypoxia and hypercapnia. Treatment should follow local protocol; typically, a slow intravenous bolus of lorazepam (up to 0.1 mg/kg) is administered. If ineffective or if seizures recur, an intravenous infusion of phenytoin (15 mg/kg over roughly one hour) may be used.

Due to the risk of cardiac arrhythmias, ECG monitoring is necessary during phenytoin infusion, and the rate must not surpass 50 mg/min. Since anticonvulsants can depress the cardiovascular and respiratory systems, monitoring of blood pressure and respiration is critical.

For uncontrolled seizures, an intravenous barbiturate, often thiopental, is required. Administration must be by an expert, such as an anesthetist, as it necessitates intubation and controlled ventilation. Neuromuscular blocking drugs should never be used alone, as they do not stop convulsions and only induce muscle paralysis. This procedure is typically carried out in a critical care environment with EEG monitoring to ensure burst-suppression. Expert consultation is crucial.

Exposure

Exposure to cold environments can lead to hypothermia in trauma patients. However, there is no evidence to suggest that mild hypothermia is advantageous during the initial management of a head injury in the Emergency Department. Hyperthermia can occur later as a result of certain brain injuries. When identified, it should be managed with active cooling methods such as ice packs, fans, and intravenous paracetamol or metamizol.

Investigations

Upon arrival at the trauma center, polytrauma patients undergo a CT scan of the head as part of an overall body scan, which provides critical information about any brain injuries. In cases where this is not feasible, or the patient has a standalone head injury, a CT scan is often conducted after the primary survey. This should be done in conjunction with a cervical spine (c-spine) CT if a c-spine injury has not been clinically excluded.

The sole exception is in the presence of uncontrolled hemorrhage that necessitates immediate surgical intervention.

Indications for immediate CT following cranial trauma include:

- GCS score at any point post-injury
- GCS score less than 15 two hours post-injury
- Suspected open or depressed skull fracture
- Signs of a basal skull fracture
- Post-traumatic seizure
- Focal neurological deficit
- More than one episode of vomiting (clinical judgment advised if under 12 years)
- Amnesia for events preceding the impact (not applicable in very young children)

Sensitivity: 99%. Specificity: 47%.
CT head is required for minor head injury patients with any one of the following findings: **1. Age ≥ 65 years** **2. Vomiting > 2 times** **3. Suspected open or depressed skull fractures** **4. Signs suggesting basal skull fracture:** • Hemotympanum • Racoon eyes • CSF otorrhea or rhinorrhea • Battle's sign (bruising around mastoid process) 5. GCS < 15 at 2 hours post injury 6. Retrograde Amnesia > 30 min 7. Dangerous mechanism: • Pedestrian struck by vehicle • Ejection from motor vehicle • Fall from elevation >3 feet or 5 stairs
Inclusion Criteria **1. GCS 13-15** **2. Age ≥ 16 years** **3. No coagulopathy or on anti-coagulation** **4. No obvious open skull fractures**

Table 7.3 The Canadian CT head rule

Additionally, patients with the following risk factors should be carefully evaluated if they have experienced any loss of consciousness or amnesia:

- more than 65 years old.
- Coagulopathy (history of bleeding, known clotting disorder, use of anticoagulant or antiplatelet medication)
- Dangerous mechanism of injury (e.g., a pedestrian struck by a vehicle, falling from more than 1 meter or down five steps). A lower threshold should be applied for the height of a fall in young children.
-

Secondary Survey

A comprehensive head-to-toe examination should be conducted, including the specific features related to head trauma noted below. The team leader must ensure that all findings and any discrepancies in the examination are documented.

Scalp

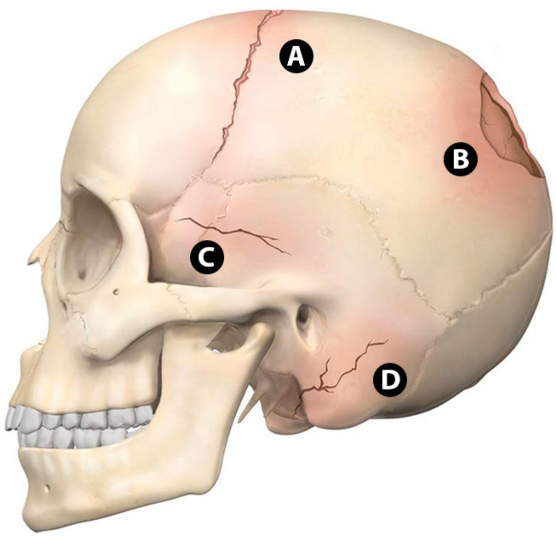
Inspect the scalp for lacerations, bruising, or swelling and carefully probe any cuts for a linear or depressed skull fracture at the base. Sometimes, a hematoma in the loose areolar tissue may mimic a fracture. Open fractures that expose brain tissue should not be probed but instead covered with a sterile dressing and reserved for specialist evaluation.

Foreign objects emerging from the skull must be left for removal by neurosurgeons. Significant scalp hemorrhage should be managed by applying direct pressure on the edges or using hemostats to clamp the aponeurosis and fold the scalp onto itself. For wound closure, deep sutures or a skin stapler may be employed.

Base of Skull

Examine the patient for any clinical indications of a basal skull fracture. This structure extends along a line connecting the landmarks of the mastoid process, tympanic membrane, and orbits.

SKULL FRACTURE



TYPES OF FRACTURES

- A Diastatic fracture
- B Depressed fracture
- C Linear fracture
- D Basilar fracture

Figure 7.1 Skull Fracture

Signs and symptoms of basilar skull fractures are linked to the skull base's proximity to cranial nerves, blood vessels, and meninges—the protective membranes surrounding the brain and spinal cord that contain cerebrospinal fluid (CSF). Skull base fractures heighten the risk of meningitis due to potential bacterial contact from the nose, throat, or ear with the central nervous system.

Skull base fractures can be categorized by their location, affecting the anterior, middle, or posterior fossa. Anterior basilar skull fractures are marked by "raccoon eyes," indicating bruising around the eyes. These fractures may also lead to CSF leakage through the ears or nose, producing the "halo" sign—a double ring pattern on an absorbent surface where CSF mixes with blood. Other indicators of anterior basilar skull fractures include loss of vision and smell, along with eye movement defects from cranial nerve damage.

Middle skull base fractures, which are the most prevalent, primarily impact the temporal bone and inner ear. They are linked to carotid artery damage, hearing loss, and balance issues. These fractures may cause blood to accumulate behind the eardrum, giving it a purple appearance, and may also cause bruising behind the ear, known as the Battle sign.

Lastly, posterior skull base fractures are connected with cervical spine injury, vertebral artery injury, and harm to the lower cranial nerves. Though less common, these fractures pose a threat to the brainstem, which can be lethal.

The Battle sign in a basilar skull fracture is a crescent-shaped bruise that appears behind one or both ears over the mastoid process

Blood leaking from the nose or ear can be tested for cerebrospinal fluid (CSF) using the beta-transferrin test, which can detect as little as 2% CSF contamination in body fluids. If CSF is present with the blood, a double ring pattern will appear. Additionally, the presence of CSF can delay the clotting of any blood discharge, though this is not a very reliable indicator.

Administering antibiotics routinely has not been proven beneficial in cases of skull base fractures, even when a CSF leak suggests a compound fracture. Antibiotics are typically reserved for patients with depressed compound fractures to prevent meningitis and abscess formation. The choice of antibiotics will depend on local protocols, which should be familiar to the team leaders.

If there is a fractured skull base, a nasogastric tube should not be used, as it may be inadvertently inserted into the cranial vault. Therefore, the orogastric route is generally safer for gastric drainage in an unconscious patient with a head injury.

Severity of head injuries

Head injuries are categorized by several criteria: the severity of the injury as determined by the Glasgow Coma Scale (GCS; mild, moderate, severe); the mechanism of injury (blunt or penetrating); and the type of injury (skull fractures or intracranial lesions). Introduced in 1974, the GCS is extensively utilized to initially assess brain injury severity.

The GCS is instrumental in measuring neurological function and has been employed to forecast both immediate and long-term outcomes following a head injury. A GCS score of 9 or below indicates a severe brain injury, 9 to 12 suggests a moderate head injury, and 13 to 15 signifies a mild head injury.

Criteria	Mild	Moderate	Severe
Structural imaging	Normal	Normal or abnormal	Normal or abnormal
Loss of Consciousness (LOC)	0–30 min	> 30 min and < 24 hrs	> 24 hrs
Alteration of consciousness/mental state (AOC)	A moment up to 24 hrs	> 24 hours. Severity based on other criteria	-
Post-traumatic amnesia (PTA)	0-1 day	> 1 and < 7 days	> 7 days
Glasgow Coma Scale (best available score in first 24 hours)	13-15	9-12	< 9

Table 7.4 Classification of TBI Severity

REF: Adapted from: Kane SF, Saperstein AK, Bunt CW, Stephens MB. When war follows combat veterans home. J Fam Pract. 2013;62(8):399-407.

Referral to a Neurosurgeon

Patients who potentially or actually require neurosurgical intervention should be referred to a neurosurgeon. This includes patients classified under 'severe head injury' and those who require a CT scan (as indicated in table 8.3) but cannot have it performed within 2-4 hours.

Communication with a Neurosurgeon

Not all patients discussed with a neurosurgeon will require admission under their care; however, their advice on investigation and treatment can be invaluable.

Information Required by a Neurosurgeon

- Your identity and your request
- Patient's name, age, and gender
- Time and mechanism of injury
- Neurological condition at the scene (description)
- Any changes in neurological status during transport to the hospital
- Initial assessment (ABCDE)
- Signs of neurological injury or seizures
- Treatments given and responses observed
- Other injuries sustained
- Results of any investigations conducted
- Relevant past medical history and medications

Treatment Strategies

The following treatments are recognized for head injuries but should not be routinely used and ideally only after consultation with a neurosurgeon.

Mannitol is an osmotic diuretic agent that reduces intracranial pressure (ICP) through two mechanisms. Initially, it improves cerebral blood flow by altering the deformability and size of red cells. Additionally, it decreases interstitial brain volume by creating an osmotic gradient that facilitates water movement from brain tissue to blood. However, in areas where the blood-brain barrier is compromised, mannitol may seep into the brain tissue, increasing local water content. The starting dose is 0.5 g/kg (equivalent to 175 ml of 20% Mannitol for a 70 kg adult), after which the patient is reassessed, for instance, for pupil size reduction. A urinary catheter is necessary if not already in place. Repeated doses may lead to hypovolemia or electrolyte imbalances.

Elevate head of bed to 30-45° Cause venous outflow from the brain to improved, therefore helping to reduce ICP Contraindications: hypovolemia, spine injury

Hypertonic Saline (HTS) is increasingly utilized to manage elevated ICP following traumatic brain injury (TBI). HTS, also an osmotic agent, draws fluid from swollen cerebral tissue, aiding in controlling ICP and mitigating the harmful effects of secondary brain injury. Standard preparations range from 1.8% to 10% solutions. A typical dose is 100 mg/kg hypertonic NaCl (for example, 1 ml/kg of a 10% solution or 1.25 ml/kg of a 7.5% solution) administered over 10 minutes. Both mannitol and HTS are effective in treating increased ICP, but HTS also has the benefit of increasing intravascular volume without causing osmotic diuresis.

Furosemide is a powerful diuretic that lowers ICP by reducing brain water content and the rate of cerebrospinal fluid (CSF) production. It can be administered as an alternative to mannitol at a dose of 0.5 mg/kg. Furosemide's impact on ICP can be enhanced when used with mannitol or hypertonic saline. Nonetheless, it is important to monitor for potential hypovolemia, hypotension, and biochemical disturbances.

Hyperventilation has been previously addressed. Its application should be limited to situations of impending coning, alongside other treatments such as mannitol.

At present, there are no neuroprotective drugs available. The administration of steroids is discouraged due to their lack of beneficial effects and correlation with poorer outcomes.

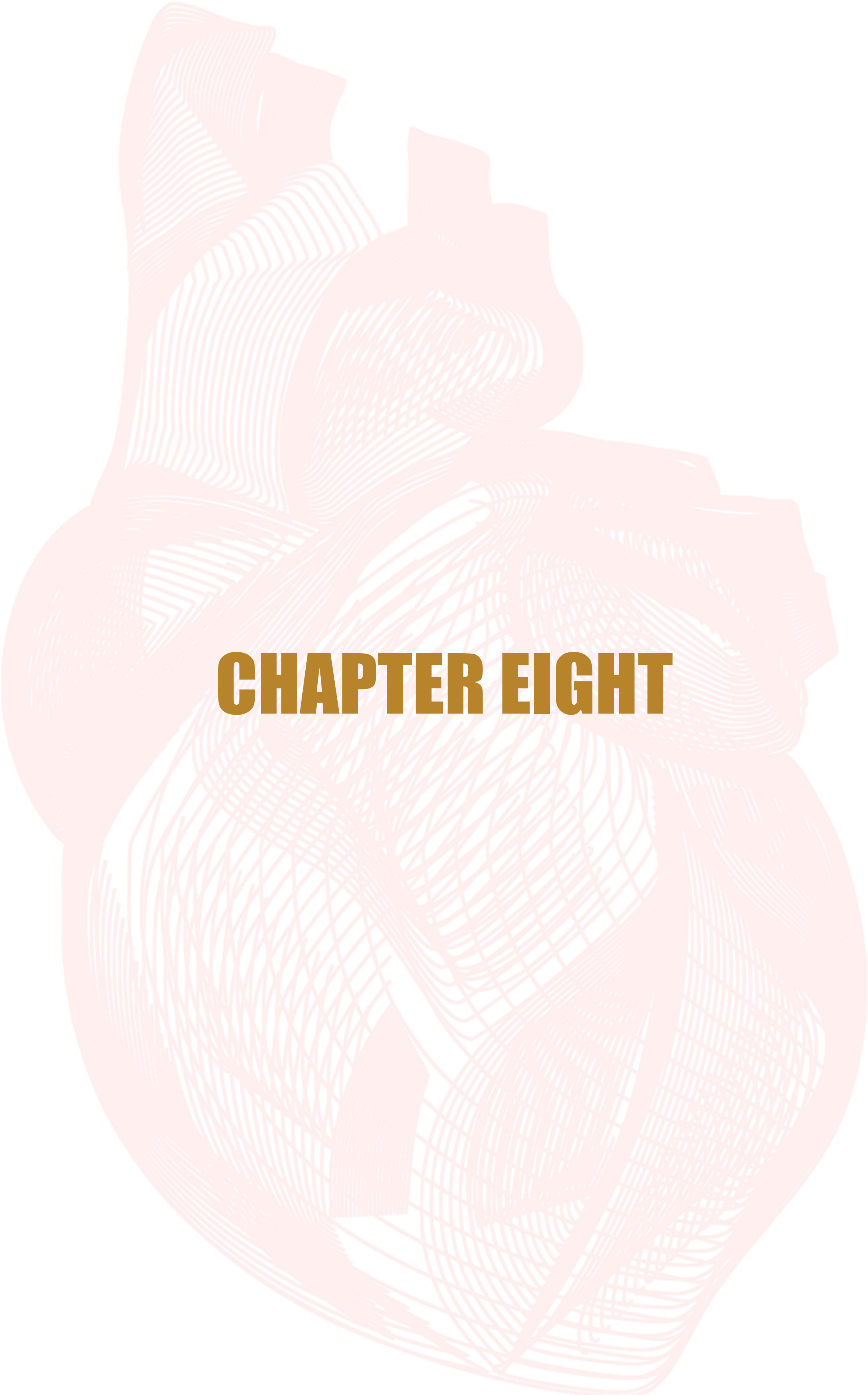
Gathering details of any pre-existing medical and neurological issues is crucial, as they can cause trauma through a loss of consciousness or present signs and symptoms that resemble those of a traumatic brain injury.

Patients with traumatic brain injury (TBI) are at an increased **risk for venous thromboembolic** events, which can lead to significant morbidity and mortality. The estimated risk of deep venous thrombosis (DVT) without prophylaxis is 20% following severe TBI. Evidence suggests that compression stockings may be used for DVT prophylaxis in patients with severe TBI, barring lower extremity injuries. Prophylaxis with low-molecular-weight heparin (LMWH) is also supported for DVT prevention in these patients. However, there is no reliable data to guide recommendations on when to safely initiate pharmacological prophylaxis, nor can specific recommendations be made regarding the choice of medication or dosing regimen.

should be measured at least every six to eight hours. Indications for ICP Monitoring: GCS < 8 with abnormal CT scan, GCS < 8 with normal CT scan and 2 of the following: Age > 40, B/P < 90 mmHg systolic, and Posturing.

Medical and Neurological Disorders that Complicate Trauma

- Hypoglycemia, Hyperglycemia
- Non-traumatic Subarachnoid Hemorrhage
- Seizures
- Acute Coronary Syndromes
- Cardiac Arrhythmia
- Cerebrovascular Accident (Stroke)
- Vasovagal Attack
- Medications (especially anticoagulants and antiplatelet drugs)
- Alcohol, Recreational Drugs



CHAPTER EIGHT

Trauma to the vertebral column and spinal cord

Learning Objectives:

At the end of this chapter, the reader will be able to :

- Predict spinal injuries based on the mechanism of injury.
- Assess the vertebral and spinal injuries.
- Select the appropriate investigations and imaging for a patient with vertebral and spinal injuries.
- Know how to manage different types of vertebral and spinal injuries.

Introduction

In all major trauma cases, a high level of suspicion for vertebral column injury (VCI) and spinal cord injury (SCI) is warranted. Recent studies show inconsistency, indicating that 2-15% of polytrauma patients might suffer from SCI, leading to a significant risk of permanent morbidity. Often, these victims are young, and such injuries pose a substantial societal impact.

The KSA has one of the highest rates of spinal cord injuries worldwide. According to the Global Burden of Disease report, traumatic injuries represent 22.6% of years of potential life lost in Saudi Arabia.

307 TSCI patients were admitted to Riyadh Military Hospital in Saudi Arabia from January 2003 to December 2008: 88% were male, and their mean age was 29.5 years old were the main cause of TSCI (85%).

TSCI in Saudi Arabia affects mainly the male population. The rate of RTAs caused by four-wheeled vehicles is the highest globally reported RTA statistic. Primary prevention strategies specific to the region should be developed to decrease the number of car accidents. The higher-than-expected rate of complete injuries may reflect practices in acute management and transport, and suggests that a review of the acute and integrated management of TSCI may also be necessary.

The majority of spinal injuries (60%) occur in young, healthy males aged 15 to 35, with cervical spine injuries being the most common. Blunt trauma, primarily from motor vehicle accidents (48%), followed by falls (21%) and sports injuries (14.6%), is the leading cause of these injuries. Assault and penetrating trauma make up about 10–20% of cases. Spinal column and cord injuries significantly contribute to disability, predominantly affecting young, healthy individuals and carrying substantial socioeconomic impacts.

Up to 60% of patients with spinal cord trauma also sustain other injuries; 25-50% have a concurrent head injury, while 5-10% of those with head trauma will have a spinal cord injury.

The combination of abdominal and thoracic trauma, especially when accompanied by severe hemorrhage, significantly increases the fatality rate beyond that of either injury alone.

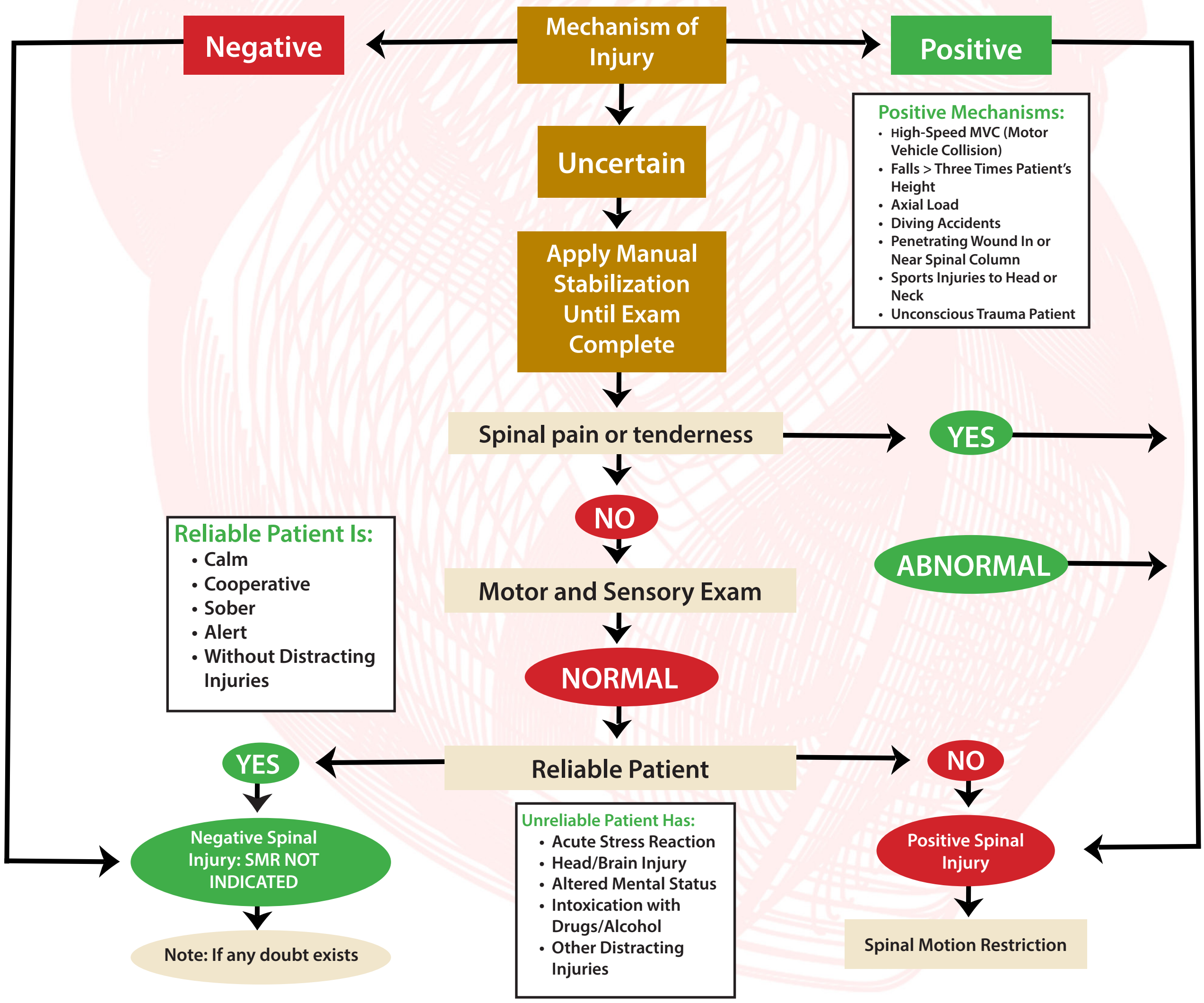
Initial and Primary survey

Spinal Cord Injuries (SCI) are present in 20-35% of patients with multiple traumas. The co-occurrence of abdominal and thoracic trauma is particularly worrisome. When coupled with severe hemorrhage, the mortality rate surpasses that of either injury by itself. Thus, the pre-hospital and early in-hospital care of severely injured patients must always consider the potential for, and the necessity of, managing injuries to the vertebral column and spinal cord.

The pre-hospital management of patients with potential spinal cord injuries demands meticulous attention to minimize secondary SCI and the associated morbidity from spinal immobilization. This involves: understanding the injury mechanism; triaging to facilities specialized in SCI; alerting the receiving hospital about incoming patients with spinal, head, or multiple injuries; and implementing full spinal immobilization with semi-rigid collars, spinal boards, which has been standard practice for years.

In the initial assessment of a patient; the designated life support protocol for spinal cord injuries is advised. This includes the "ABCDE" evaluation, ensuring airway patency while establishing spinal immobilization measures, along with assessing breathing and circulation. To immobilize the spine, use a cervical rigid neck brace, head immobilization, and a spinal board for all unconscious patients and those conscious patients reporting spinal pain. Immobilization should be maintained until spinal or medullary injuries are ruled out or definitive treatment is administered.

Algorithm 8.1 Assessment of Spinal Injury Clinical Criteria



Most patients suspected of having VCI or SCI will be fully immobilized upon arrival at the hospital. For those who are not, there are two methods to transfer the patient onto an Emergency Department trolley:

- A scoop-stretcher from an ambulance can be slid under the patient. The patient's head and neck are manually immobilized before they are lifted onto the stretcher.
- A manual transfer requires a five-person team trained in the procedure. One person secures and controls the patient's head and cervical spine with their hands and forearms. Three team members position themselves to lift the patient: one supports the thoracic spine, another the lumbar spine and pelvis, and the third supports the legs (refer to figure). On the controller's signal, the team lifts the patient gently while a fifth member slides out the trolley. The patient should not be bent or twisted during any part of this process.

Figure 8.1 Manual transfer

The presence of an underlying vertebral and/or spinal cord injury should be presumed until it is definitively ruled out by both clinical and radiological examination. Furthermore, it is crucial for the team leader to ensure that these patients are handled in a way that prevents secondary injury to the spinal cord.

When securing the airway, it is crucial to stabilize the neck in a neutral position without applying any distracting forces.

If the spine is not stabilized, the best initial approach is to ask the patient to maintain a neutral head position. For an unconscious patient, manual in-line stabilization (MILS) should be applied. If the patient is wearing a motorcycle helmet, it should be removed by two trained individuals; one should gently spread the helmet apart and rock it off the head until it can be lifted away, while the other secures the cervical spine from below.

MILS should be replaced with head blocks, tapes, or a vacuum mattress as soon as possible, following local protocols. If the patient cannot tolerate these, MILS should be continued. Should it become necessary to remove the collar and blocks, immediate reapplication of MILS is required. While semi-rigid collars and other immobilization devices are effective at limiting movement, they can cause significant issues such as discomfort, pressure sores, increased intracranial pressure, aspiration risk, and restricted breathing. Hence, these devices should be removed as soon as spinal column or cord injuries are definitively ruled out.

Conscious patients suspected of spinal injury who are confused, restless, and agitated, refusing to lie down, can pose a challenge. Under no circumstances should these patients be forcibly restrained; instead, they should be reassured and permitted to move freely, however safety of the medical personnel is of paramount importance and the patient can be sedated and mechanically ventilated if necessary to prevent harm to self or medical staff.

Muscle spasms from spinal injuries cause a conscious person to instinctively immobilize their head and neck, thus avoiding movement. Consequently, it is rare for such patients to exacerbate their spinal injury through voluntary movement. The team must endeavor to identify and address the cause of the restlessness, which is commonly attributed to pain, fear, a full bladder, or language barriers.

Intubation in these patients is more challenging due to the necessity of maintaining absolute neck immobilization. Uncontrolled intubation attempts may result in hyperflexion or hyperextension of the cervical spine, potentially causing or worsening vertebral or spinal cord injuries, and can be fatal. To minimize these risks, intubation should be performed by an experienced anesthetist skilled in using specialized equipment, such as a fiberoptic laryngoscope. The preferred technique involves the use of sedative and neuromuscular blocking drugs to facilitate tracheal intubation by trained personnel. The choice of neuromuscular blocking drug will vary based on local policy and individual preference; however, the administration of succinylcholine to patients with recent spinal cord injuries may lead to severe bradycardia, and after 48 hours, to significant hyperkalemia and cardiac arrest.

Emergency drug-assisted tracheal intubation should be executed with the semi-rigid collar removed and replaced with manual in-line stabilization (MILS), necessitating a team-based approach typically led by the airway doctor. Once the trachea is successfully intubated, the cervical collar should be reapplied. Supraglottic airway devices serve as valuable alternatives for airway management, especially when intubation is difficult. Accordingly, these devices should always be accessible as per local protocol when attempting intubation.

Breathing and Ventilation

Life-threatening thoracic injuries that pose an immediate risk must be identified and managed as outlined previously. The level of spinal cord injury may result in paralysis of the accessory respiratory muscles, intercostals, and abdominal muscles; an injury to the upper cervical region (C3- C5) level will lead to a loss of most respiratory muscle activity, resulting in acute respiratory failure and hypoxia due to hypoventilation. Injuries below this level may spare the diaphragm but paralyze the intercostal and abdominal muscles, causing diaphragmatic breathing characterized by paradoxical chest and abdominal movements during spontaneous ventilation. This could be an early indication of a significant cervical spinal cord injury. Additionally, there will be inadequate coughing, a decrease in vital capacity, reduced functional residual capacity, and a loss of active expiration.

Regular reassessment of breathing and ventilation is crucial, as conditions may deteriorate over time. It is important to consider arterial blood gas analysis early on to assess the sufficiency of oxygenation and ventilation.

Circulation

Assessment and management follow the guidelines outlined previously in the shock chapter; control external hemorrhage with direct pressure, secure IV access, and take blood for crossmatching and relevant tests. **Hypotension might stem from neurogenic shock, but hemorrhagic shock must also be ruled out.** While it's possible to differentiate between the two, they can coexist, and severe hemorrhage from concurrent injuries can worsen hypotension. Additionally, the inability to feel pain may conceal life-threatening injuries, such as pelvic or intra-abdominal trauma, which the patient may not notice. Regardless of the cause, resuscitation using the previously described principles is necessary; hypotension can lead to secondary neurological damage to the spinal cord and must be promptly addressed and managed.

Neurogenic shock is characterized by vascular hypotension and bradycardia due to spinal cord injury. It typically occurs after an injury above the T6 level, leading to a gradual loss of sympathetic outflow and vasomotor tone as the lesion level ascends. This condition results in hypotension due to arteriolar and venous vasodilation in the peripheral and splanchnic vasculature. The vasomotor tone and peripheral vasodilation increase with the lesion's height.

A lesion above T2 also causes bradycardia and decreased stroke volume because of the loss of sympathetic heart innervation. These changes lead to blood pooling in the limbs and reduced central venous return. Consequently, neurogenic shock can present with a systolic blood pressure (SBP) below 70 mmHg and a heart rate under 60 beats per minute, even when normovolemic. Additionally, patients with such conditions cannot normally respond to hypovolemia from other injuries. It is important not to confuse Neurogenic Shock with Spinal Shock, which is a temporary state of areflexia or hyporeflexia and autonomic dysfunction following a spinal cord injury.

Spinal shock is a reversible state of areflexia/hyporeflexia and autonomic dysfunction that occurs with spinal cord injury.

In an unconscious patient, these symptoms may be the sole indicators of a significant spinal cord injury (SCI). Additionally, the absence of sympathetic activity can reveal intense parasympathetic responses, such as severe bradycardia during laryngoscopy. Atropine is recommended only for patients with severe symptomatic bradycardia, considering its substantial impact on heart rate and potential side effects.

Patients may need intravenous vasopressors and/or positive chronotropic drugs; hence, inserting a central venous line early is crucial for monitoring and managing fluid response.

Regarding fluid resuscitation, crystalloids or colloids should be administered as per local guidelines. It is advised to avoid glucose-containing fluids for two main reasons: their rapid metabolism can lead to 'free water' accumulation, promoting edema, and the associated risk of hyperglycemia, which can elevate lactate levels and lower pH, potentially worsening outcomes.

Disability

During the initial assessment, symmetrical weakness may be observed. It's important to record this observation, but a comprehensive neurological evaluation should be deferred until the secondary survey is conducted.

Exposure and environmental

Patients must be fully undressed for a thorough examination, with their dignity preserved. Rapid cooling is a risk, especially for those with spinal cord injuries who cannot regulate their body temperature due to associated vasodilation. Efforts to reduce heat loss should include blankets, warm air blowers, or overhead heaters, while avoiding hyperthermia, which can exacerbate neurological damage. The goal is to maintain normothermia.

For conscious patients, minimal handling is crucial, and all maneuvers and procedures should be explained in advance. It is also vital to prevent any twisting of the spine, necessitating a coordinated log roll for back examinations and spinal board removals.

Secondary survey

As previously mentioned, this involves a comprehensive examination from head to toe to identify any injuries not evident during the initial assessment. It is often during this stage that a vertebral column injury (VCI) or spinal cord injury (SCI) may be detected. Consequently, if the secondary survey is postponed for any reason, such as the necessity for emergency surgery, it is imperative to continue spinal immobilization. Additionally, the need for a spinal examination should be explicitly recorded in the patient's medical records and communicated to the clinician overseeing the subsequent in-patient care during the handover.

Several signs and symptoms are indicative of a spinal injury: pain in the spine at the injury site that worsens with movement; areas of abnormal or lost sensation; unawareness of other injuries, especially fractures, when not under the influence of intoxicants; and the presence of weakness or paralysis in one or more limbs. Unawareness of other injuries, particularly fractures when not under the influence of intoxicants, and the presence of weakness or paralysis in one or more limbs are also indicative.

If Whole Body CT scanning is included in the primary survey, log rolling is not prioritized in cases of blunt trauma. It may lead to fracture dislocation, pain, distress, or clot disruption in patients with pelvic fractures or other injuries. The classical log roll is only performed when immediate imaging is not available and is intended to detect superficial lacerations, wounds, bruising, swelling, and deformity, which are external indicators of vertebral column injury. The entire spine, from the occiput to the coccyx, is palpated to identify any tenderness, irregularities, deformities, and gaps between the spinous processes. Additionally, a rectal examination may be conducted to exclude sacral sparing. The presence of any signs suggesting vertebral column injury necessitates appropriate radiological investigation, in accordance with local protocols.

Prolonged immobilization on a spinal board may pose a danger to the patient. If it has not been done, the long spinal board should be removed in the Emergency Department to reduce the risk of developing pressure sores. Additionally, the condition of the pressure areas must be documented. The spinal board is primarily used for extrication and transport. The patient ought to be moved to a trauma stretcher at the earliest opportunity.

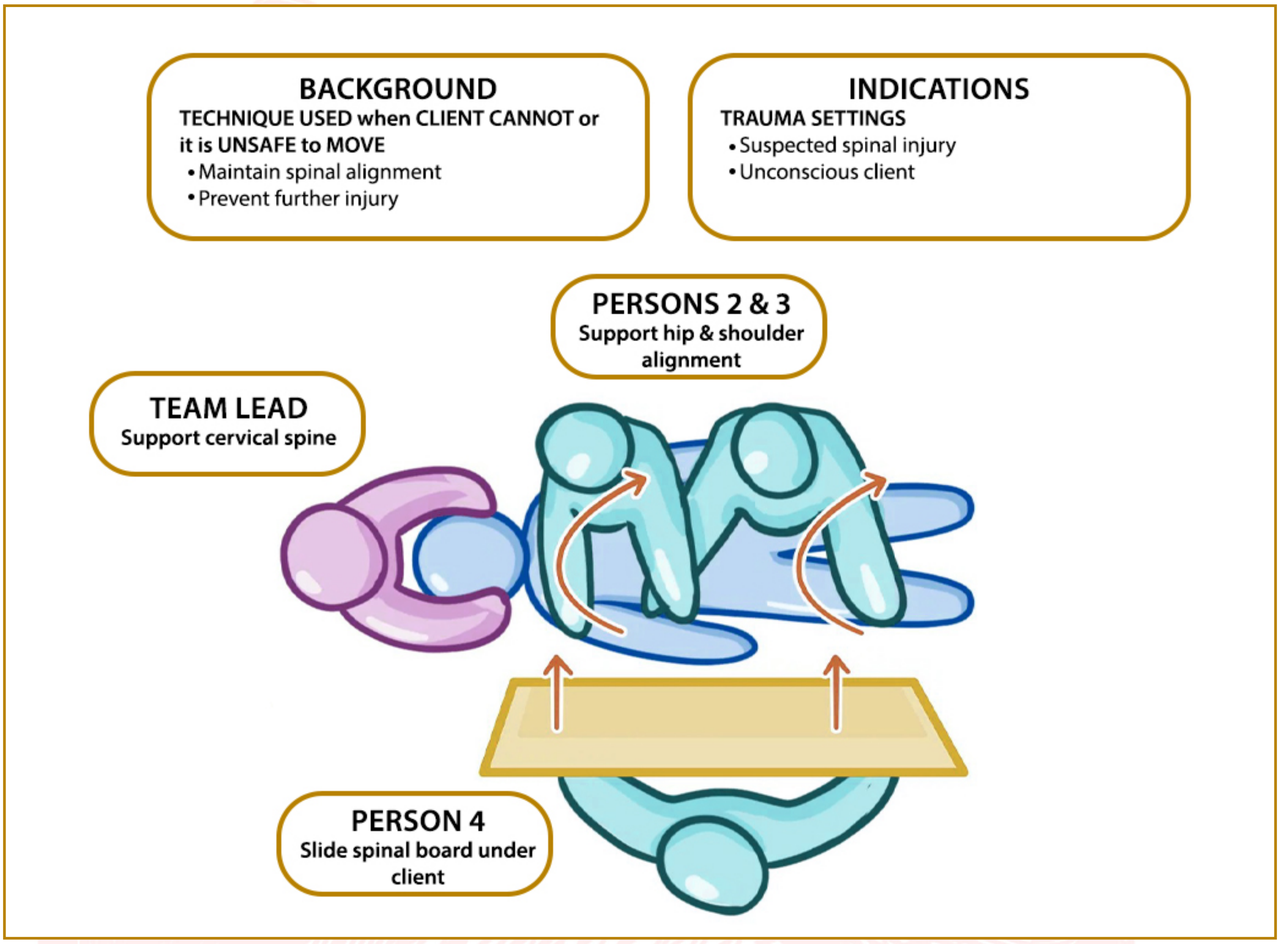


Figure 8.2 Transfer trauma patient to spinal board

Neurological function

A spinal cord injury can significantly impair or halt the transmission of sensory and motor signals, along with the functions of the autonomic nervous system. Clinicians can identify the impacted segments of the spinal cord through a systematic examination of dermatomes and myotomes.

The International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI), also known as the ASIA Exam, is an assessment protocol developed by the American Spinal Injury Association (ASIA).

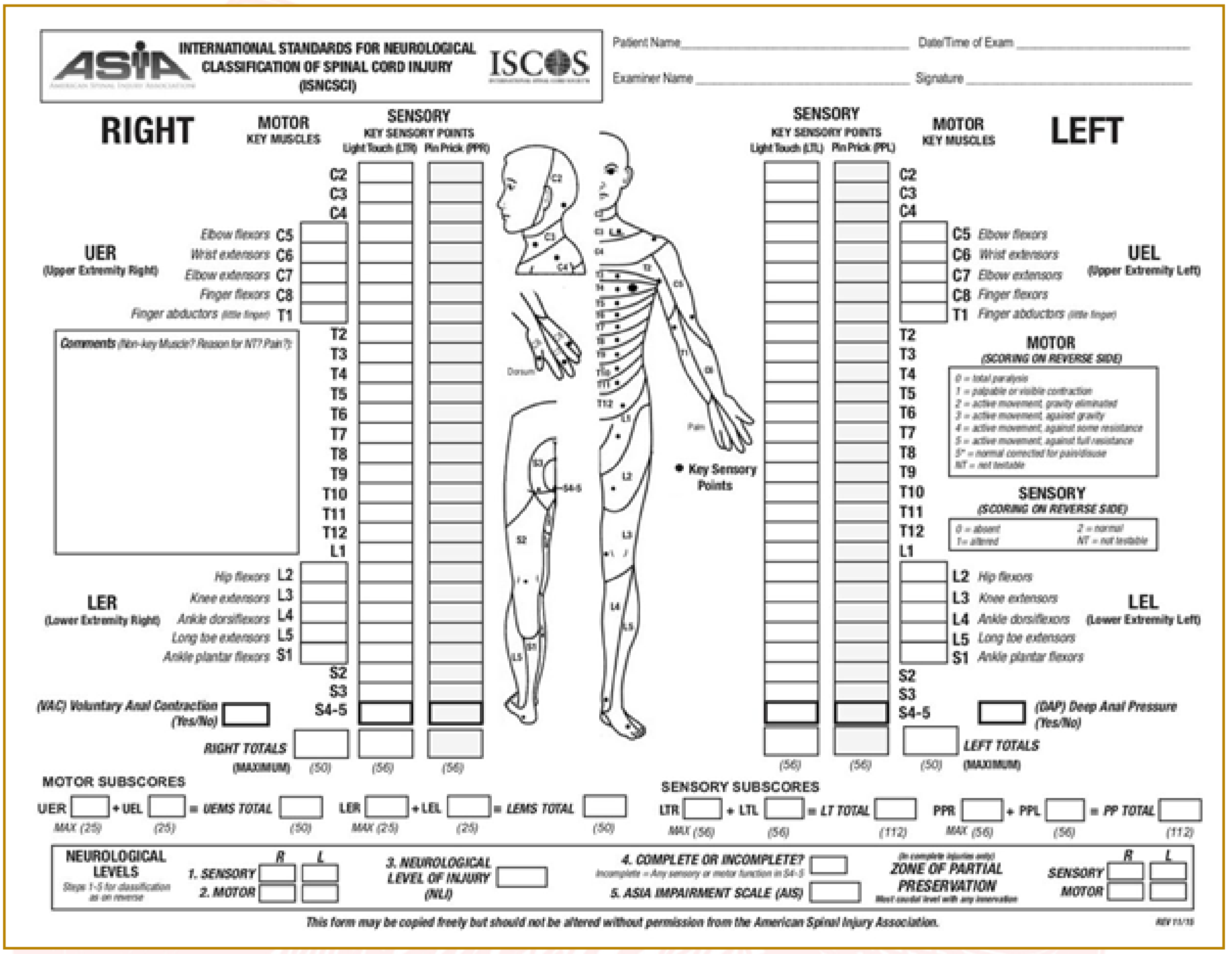


Figure 8.3 The International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI)

Dermatomes are skin areas innervated by the sensory fibers originating from a single spinal nerve root's dorsal root. These nerve roots, which are part of the peripheral nervous system, connect the nerve to the spinal cord.

Nerve roots emerge from each spinal cord level (e.g., C3, C4), and while many merge into a plexus (such as brachial, lumbar, or lumbosacral), not all do. This can lead to one nerve root innervating multiple peripheral nerves. For instance, the median nerve originates from the C6, C7, C8, and T1 nerve roots, while the ulnar nerve comes from the C7, C8, and T1 roots.

There are 30 dermatomes in total, each conveying sensations from specific skin regions to the brain. These include 8 cervical nerves (C1 does not have a dermatomal area), 12 thoracic nerves, 5 lumbar nerves, and 5 sacral nerves.

Recognizing a spinal cord injury in unconscious patients hinges on maintaining a high index of suspicion and looking for features indicative of such an injury: hypotension with bradycardia, flaccid areflexia, diaphragmatic breathing, absence of pain response below a certain dermatomal level, and priapism.

It is crucial to observe whether any spontaneous movement is voluntary or a reaction to pain and to note any asymmetry between limbs. Unconscious patients necessitate a thorough reassessment.

Types of vertebral column injuries

1. Atlanto-Occipital Dislocation (AOD) injuries typically occur in high-speed motor vehicle accidents and are often associated with a high rate of morbidity and mortality. This is due to the involvement of critical structures such as the brainstem, spinal cord, and vertebral arteries. The mechanism of injury usually involves hyperextension and distraction of the cervical spine, leading to a complete disruption of the stabilizing ligaments at the craniocervical junction. While helmets can protect against intracranial injuries, they also increase the head's weight, potentially increasing the centripetal force and predisposing to AOD. Children are particularly vulnerable because of their larger head-to-body ratio, smaller horizontal occipital condyles, and the natural instability of their necks.

2. Atlas fracture (Cl fracture)

Atlas fractures and transverse ligament injuries are traumatic conditions typically resulting from high-energy trauma with axial loading in young patients, known as Jefferson fractures, or from low-energy falls in the elderly. Owing to the spacious nature of the spinal canal at this level, these injuries often manifest as neck pain without neurological deficits.

Diagnosis can be elusive with plain radiographs, necessitating a CT scan for accurate identification. An open-mouth odontoid view is beneficial for assessing transverse ligament disruption, which can cause lateral mass displacement.

Stable injuries may be managed with a cervical collar for immobilization. Conversely, unstable injuries demand halo-vest immobilization or surgical intervention for stabilization with fusion.

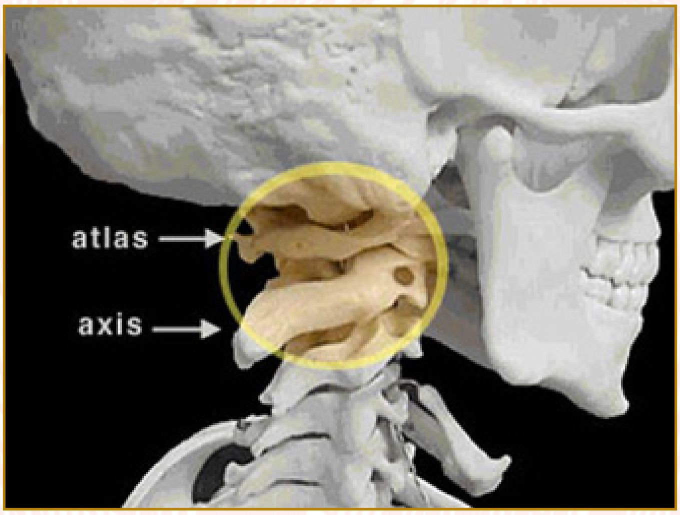


Figure 8.4 Atlas fracture (Cl fracture)

3. Atlas Subluxation Complex (ASC)

An atlas subluxation complex (ASC) occurs when the top bone in your neck, also known as the atlas, misaligns and causes nervous system dysfunction. This condition limits the ability of your brain to communicate with your body and visa-versa. An ASC is often caused by physical trauma such as a car accident, contact sports, slips & falls, the birthing process, etc. It may take from weeks, months to years for symptoms to manifest. Once an ASC is created, a stress response occurs. Your muscles will spasm and become tender, while your spinal bones lock up.

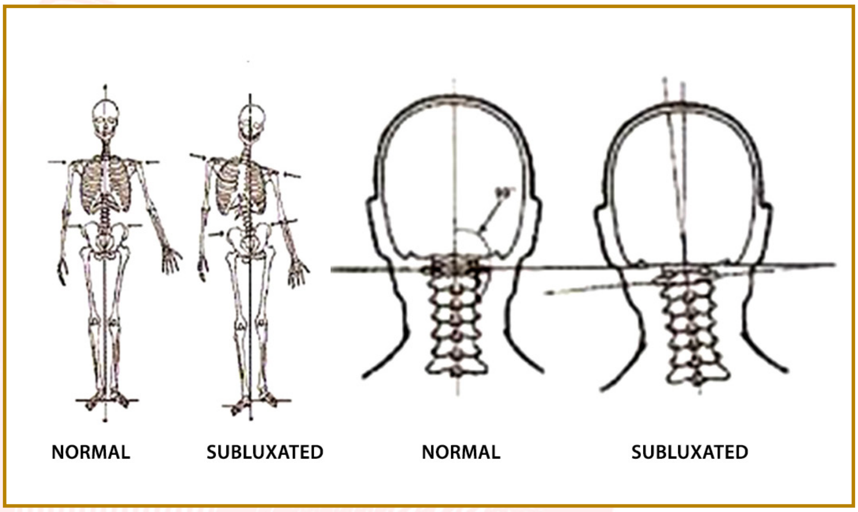


Figure 8.5 Atlas Subluxation Complex (ASC)

4. Axis fractures (C 2 fractures)

- A- Odontoid fractures

The odontoid process, also known as the dens, is a bony projection that extends upward from the second cervical vertebra (C2, or the axis). Fractures in this region are clinically significant due to their role in facilitating the primary movement of lateral rotation in the cervical spine. The classification of odontoid fractures into type I, type II, and type III reflects the variations in fracture location and shape. The main cause of injury is hyperflexion of the cervical spine, which pushes the head and the C1 vertebra backward. Such fractures are typically the result of trauma, often from high-energy impacts in younger individuals and lower-energy falls in the elderly.

The goal of treatment is to stabilize the fracture, typically through external immobilization with devices like a brace or halo vest.

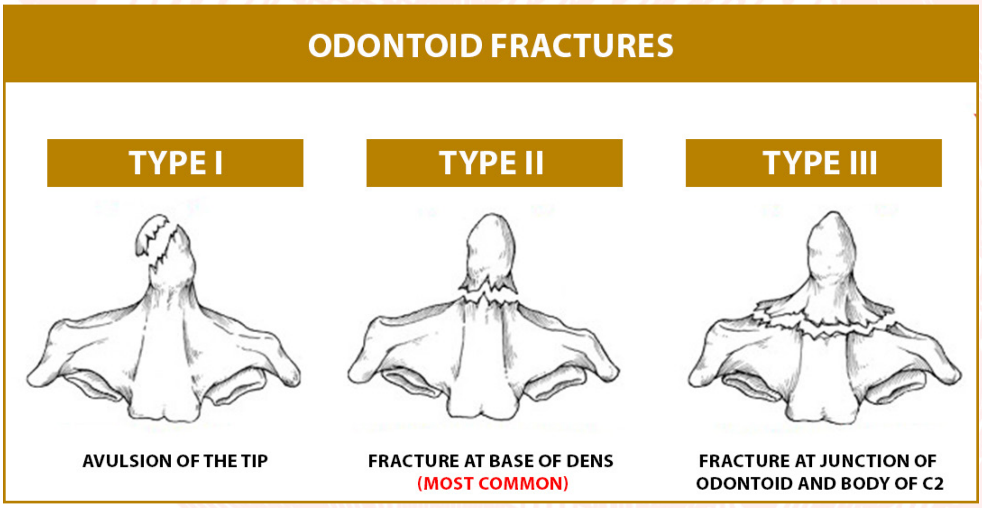


Figure 8.6 Odontoid fractures

- B- A posterior element fracture of C2

A posterior element fracture of C2, also known as a hangman's fracture, involves bilateral fractures of the posterior elements, either the pars interarticularis or pedicles. This type of fracture typically occurs due to forced extension with distraction, often seen in deceleration injuries where the patient's face strikes an object, causing forced extension of the cervical spine. Symptoms vary with the extent of dislocation and can range from isolated neck pain to stroke symptoms due to vertebral artery dissection, or even death from medullary compression.

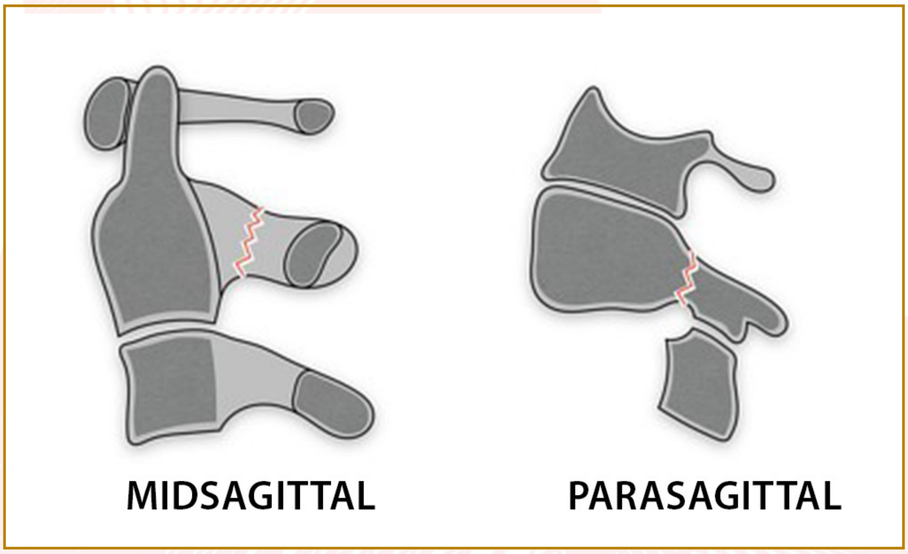


Figure 8.7 Posterior fracture of C2

Spinal cord injuries

Spinal cord injuries can generally be categorized into two types: complete and incomplete.

A complete spinal cord injury results in permanent damage to the affected area of the spinal cord, leading to conditions such as paraplegia or tetraplegia.

In contrast, an incomplete spinal cord injury involves partial damage. The extent of movement and sensation retained depends on the specific region of the spine that is injured and the injury's severity. The prognosis is influenced by the patient's overall health and medical background.

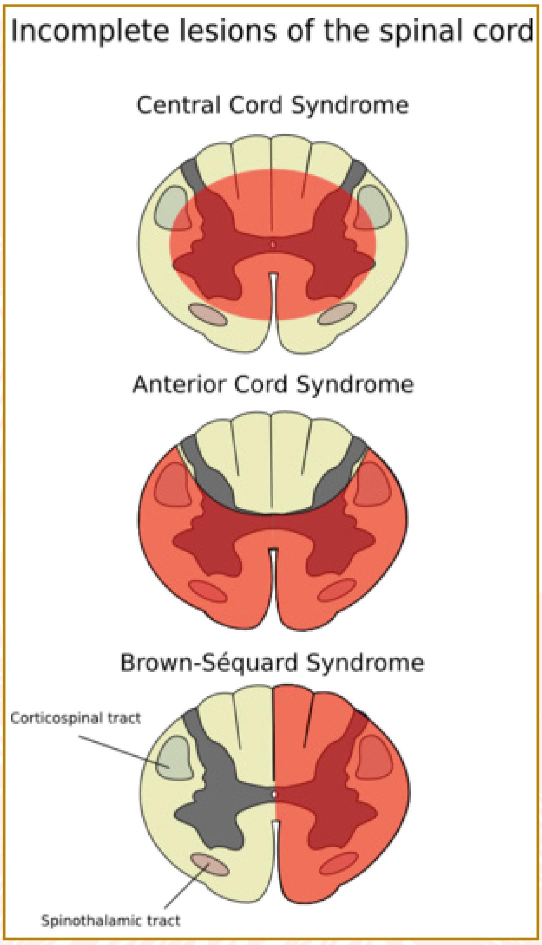


Figure 8.8 Incomplete lesions of the spinal cord

The following are the Spinal cord syndromes in incomplete spinal cord injury:

1. Central cord syndrome (CCS)

   Central cord syndrome is an incomplete spinal cord injury often resulting from a hyperextension injury to the cervical spine, which leads to spinal cord compression. Typically, this occurs when an individual falls forward, strikes their chin, and the neck is forced to extend backwards. In older patients, pre-existing cervical spondylosis often contributes to this condition. The injury may cause compression or irritation of the posterior cord by the ligamentum flavum or anterior cord compression due to the spondylosis. Such contusions can result in clinical symptoms due to edema at the injury site or, more severely, bleeding into the cord, which carries a poorer prognosis.

   The anatomical arrangement of the spinal cord means that the upper limb tracts, being medial, are more affected than the lower extremity tracts, with sacral segments positioned most laterally. Consequently, the central areas are more vulnerable to compression in the cervical cord from external forces.

   Clinically, patients present with more pronounced strength deficits in the upper extremities, particularly the hands, than in the lower extremities. Sensory deficits below the injury level are common, with variations in severity. Typically, pain and temperature sensations are compromised, and light touch may also be diminished. Sensory deficits often manifest in a "cape-like" pattern over the upper back and along the posterior upper limbs. Neck pain at the impingement site is also frequent.

Additionally, bladder dysfunction, often presenting as urinary retention, and priapism are indicative of upper motor neuron dysfunction. While sacral sensation generally remains intact, assessing rectal tone is crucial for determining the extent of compression.

The restoration of motor function typically starts with the sacral elements, progressing to the lumbar elements of the ankle, knee, and hip. Recovery of upper limb function is generally limited. It has been reported that the likelihood of some degree of functional motor recovery is approximately 75%.

2. Anterior cord syndrome

Anterior spinal artery syndrome, also referred to as anterior cord syndrome or ventral cord syndrome, is a neurological disorder characterized by motor paralysis, loss of pain and temperature sensation, and sometimes autonomic dysfunction. This condition is caused by the blockage of the anterior spinal artery, which provides blood to the front two-thirds of the spinal cord. The occlusion of this artery diminishes blood flow, leading to the infarction of the spinal cord tissue and resulting in bilateral paresis or paraplegia of the lower extremities, along with a loss of pain and temperature sensation.

3. Brown-Séquard syndrome

Brown-Séquard syndrome is characterized as an incomplete spinal cord injury pattern following a hemisection, leading to weakness or paralysis, diminished proprioception and vibration sense on the same side as the injury, and impaired pain and temperature sensations on the opposite side. The predominant causes of Brown-Séquard syndrome are categorized into traumatic and non-traumatic. Traumatic causes are more prevalent, including gunshot wounds, stabbing, vehicular accidents, blunt force, or vertebral fractures due to falls.

Clinically, ipsilateral sensory deficits in pressure, vibration, and position sense, accompanied by flaccid paralysis at the lesion's level, and spastic paraparesis below it. On the contralateral side, there would be a loss of pain and temperature sensation, typically starting 1 to 3 levels above the lesion.

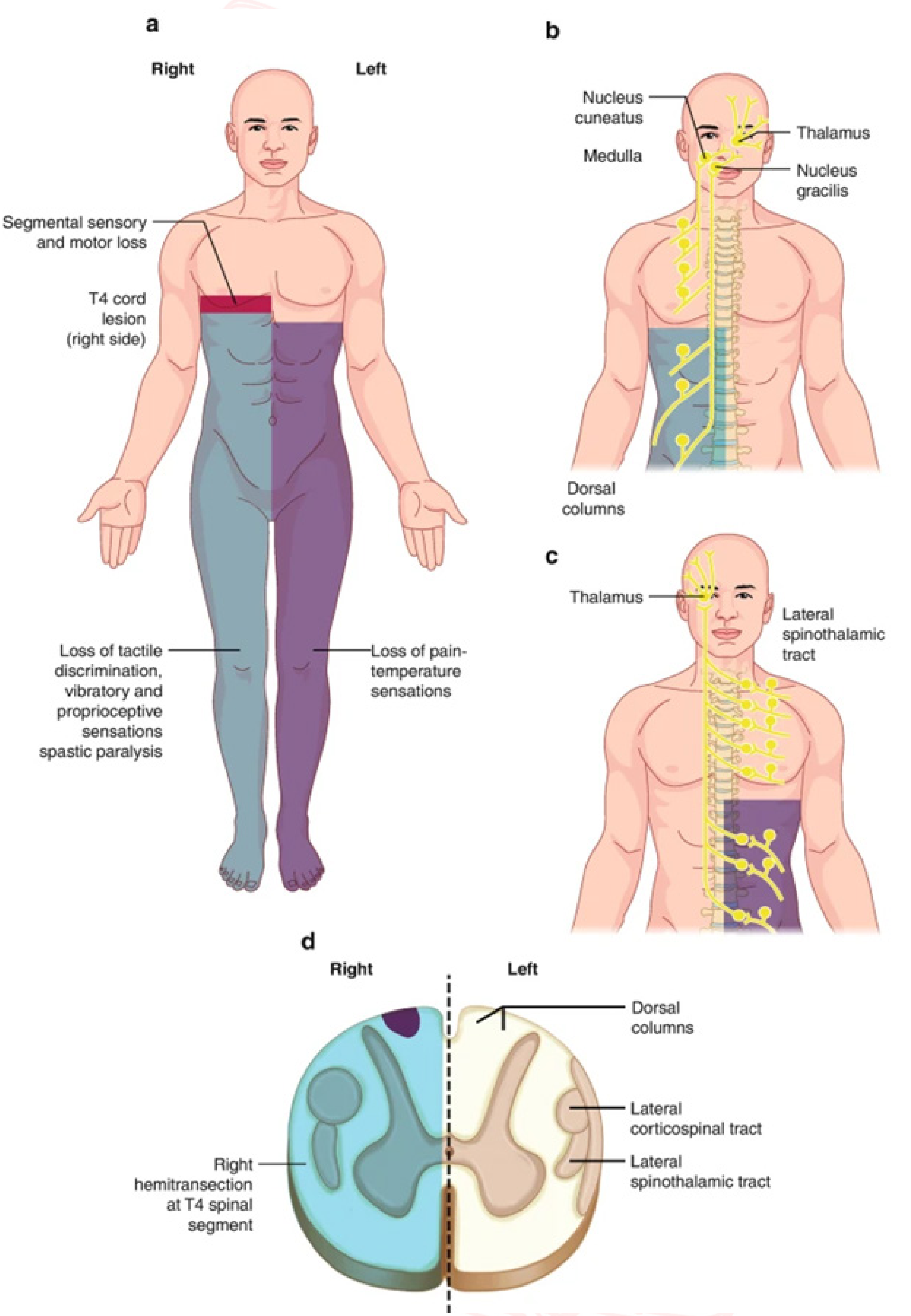


Figure 8.9 Brown-Séquard syndrome signs and symptoms

Nerve root injury

The spinal nerve root can be injured in conjunction with the spinal cord at that level or as an isolated event.

Nerve root pain arises from nerves that are either damaged or compressed within the spine. These nerves transmit information for controlling body movements and sensations to the brain. Damage to a spinal nerve can lead to pain, heightened sensitivity, numbness, and muscle weakness. This pain may stem from several nerve roots. Radicular pain is the term for pain emanating from a single nerve root.

The prognosis for motor recovery is generally positive, with approximately 75% of individuals with complete spinal cord injuries showing no deficit at the injury level or experiencing functional recovery. Those with higher cervical injuries have a 30% chance of recovering one nerve root level, those with mid-cervical injuries have a 60% chance, and nearly all patients with lower cervical fractures recover at least one nerve root level.

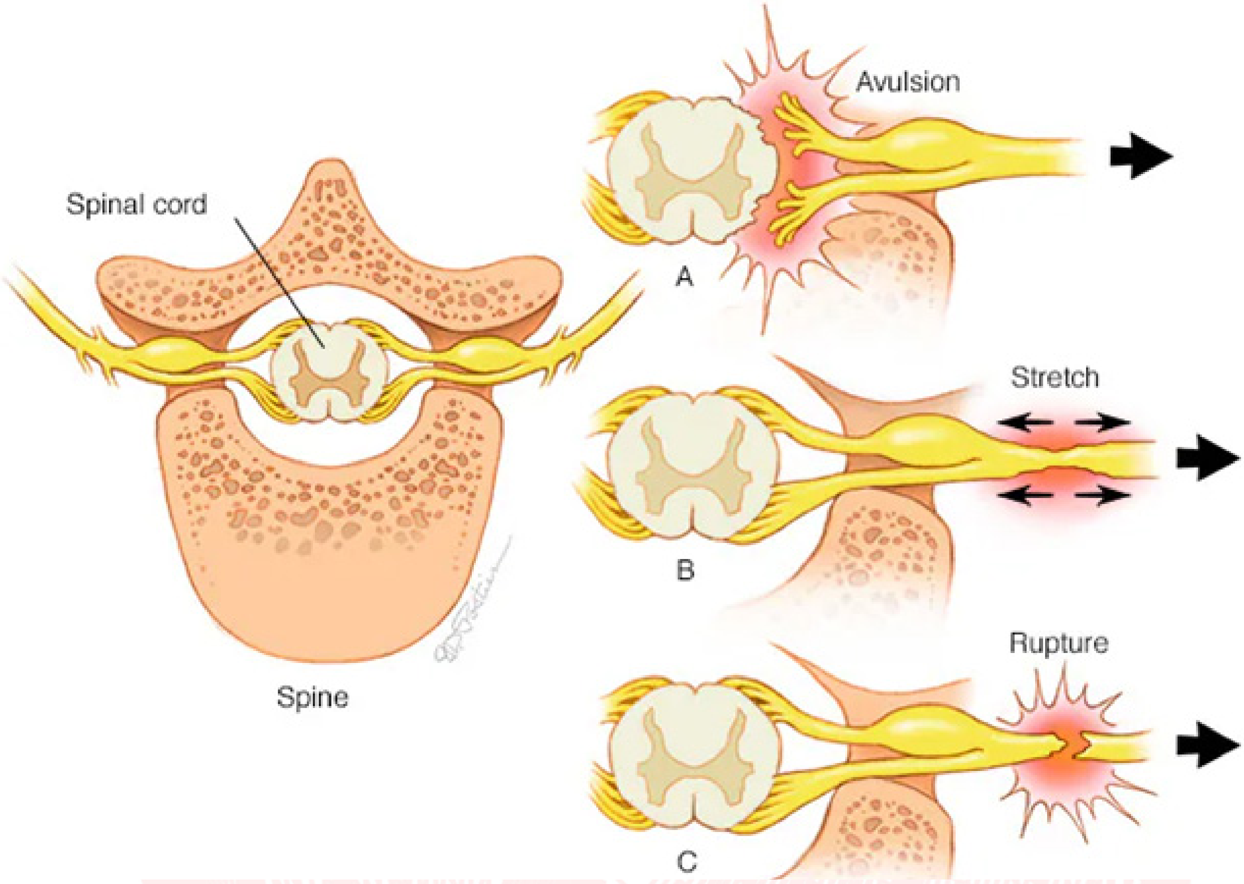


Figure 8.10 Nerve root injuries

Additional Interventions

Following the initial and secondary assessments, the patient's condition will guide further management, such as surgery. The subsequent interventions for managing suspected spinal cord injuries include:

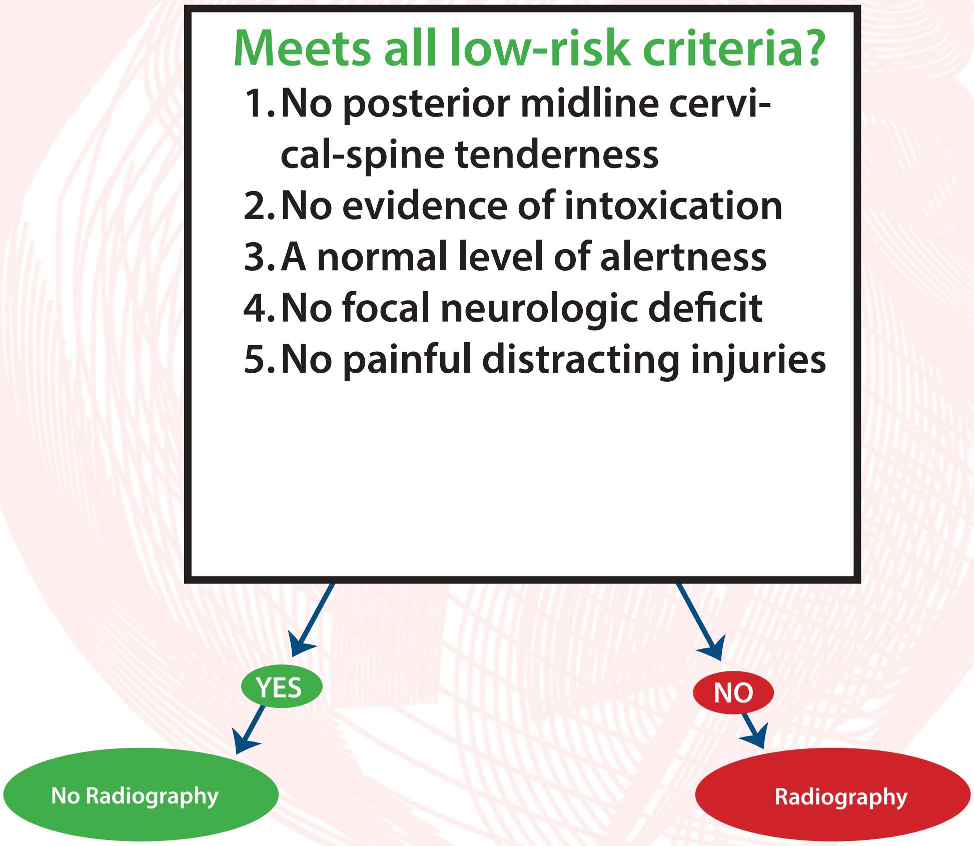
- keep head of bed elevated
- Implement measures to prevent respiratory complications, such as atelectasis, muscle fatigue, increased breathing effort, and ventilation-perfusion mismatch.
- Inserting a urinary catheter;

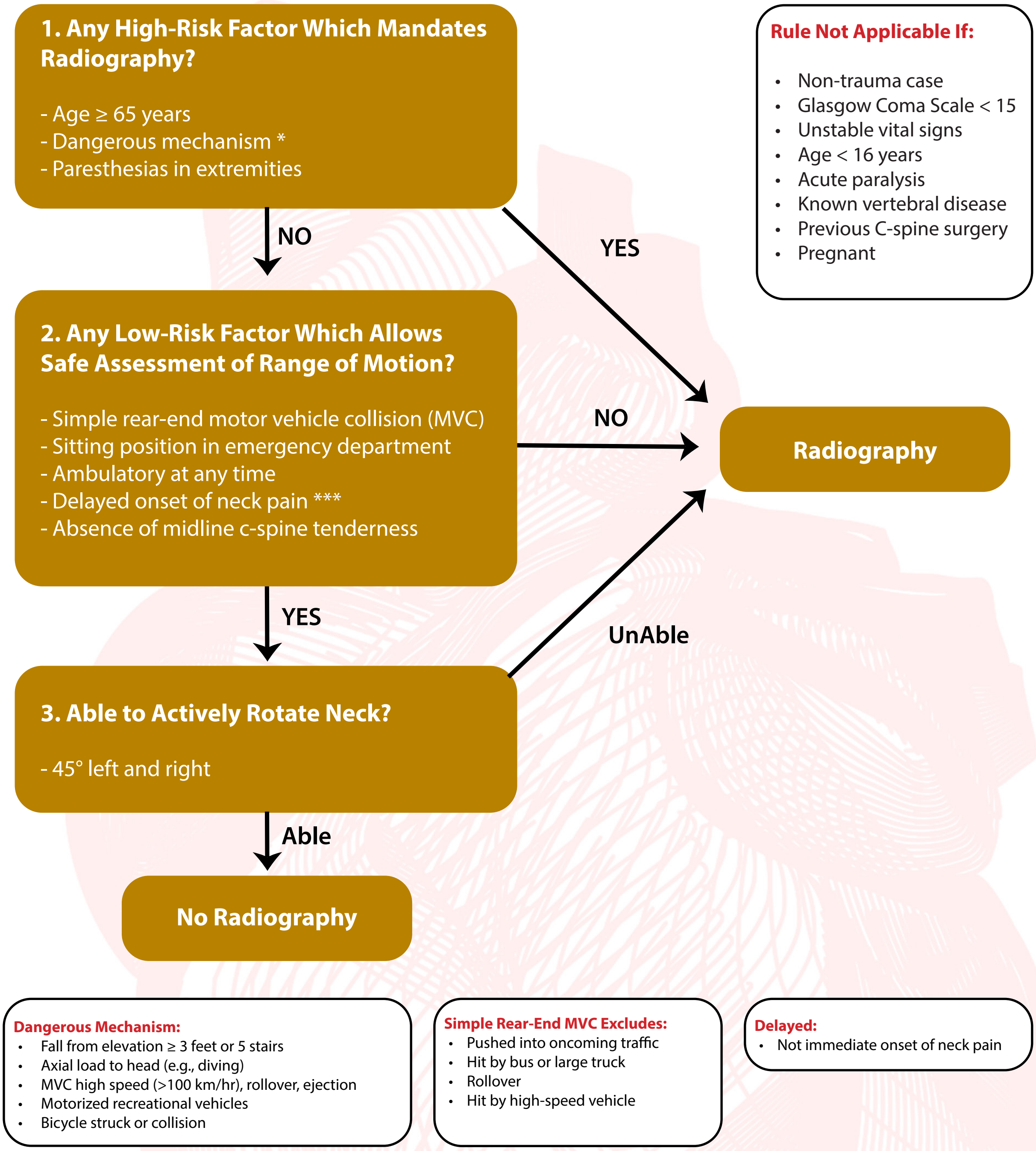
- Additionally, measures should be taken to prevent both hypothermia and hyperthermia.
- Consider the use of antiemetics and analgesics; conduct repeated neurological evaluations; remove immobilization devices as soon as possible to prevent pressure sores; monitor glucose levels to maintain a target blood glucose level within the normal range (4.0—7.0mmol/l); establish early contact with a specialist or spinal rehabilitation unit.

Clinical clearance of the cervical spine

The Canadian C-Spine Rule and the National Emergency X-Radiography Utilization Study (NEXUS) Low-Risk Criteria are established systems to determine which patients require radiological investigation of their cervical spine and who can be cleared based on history and clinical examination. For these patients, cervical spine immobilization is no longer necessary, and it is safe to remove the collar, a process commonly known as 'clearing the cervical spine'. If any criteria are met, full immobilization is continued, and appropriate radiological investigations, including antero-posterior, lateral, and open mouth views, are conducted.

Figure 8.11. National Emergency X-Radiography Utilization Study (NEXUS) Criteria





Algorithm 8.2 Cervical spine radiography criteria

Corticosteroids

Experimental studies have indicated that methylprednisolone treatment could be advantageous for spinal cord injuries. However, the current evidence regarding the use of high-dose steroids for such injuries is still inconclusive, and their routine application is not endorsed.

Investigations

CT- Scan

For patients with major trauma and/or multiple injuries, a multi-slice CT scan of the entire spine is the preferred initial imaging method. It surpasses plain x-rays in accuracy for diagnosing vertebral column injuries and reduces both total imaging time and patient handling.

CT scans are recommended in the following scenarios:

- GCS ≤ 13 upon initial assessment;
- Patient under anesthesia;
- Inadequate or suspicious findings on spinal x-rays;
- Additional indications for a CT scan;
- Dementia;
- New neurological signs or symptoms;
- Neck pain characterized as severe (>7/10) or associated with pre-existing vertebral disease.

Magnetic resonance imaging (MRI)

Magnetic resonance imaging (MRI) is the preferred method for detecting soft tissue (non-bony) injuries of the vertebral column and spinal cord. However, due to environmental constraints and the length of the procedure, the use of MRI scans is currently limited.

Plain X-rays:

The most commonly performed vertebral column x-ray is the lateral cervical spine x-ray.

CHAPTER NINE

Musculoskeletal Trauma

Learning Objectives:

At the end of this chapter, the reader will be able to :

- Understand the mechanisms of injury and clinical findings of different musculoskeletal injuries.
- Approach trauma victims with musculoskeletal injuries following a systematic approach.
- Select the appropriate investigations and imaging for a patient with musculoskeletal injuries.
- Know how to manage trauma victims with musculoskeletal injuries..
- Describe the objectives and methods of amputation procedures.

Introduction

Musculoskeletal injuries may occur due to falls, road traffic accidents, or exposure to mechanical forces. These injuries can vary from minor to severe, potentially threatening limbs or even life. Appropriate and prompt treatment of these injuries is crucial in minimizing complications and reducing morbidity.

Trauma is the leading cause of death in individuals under the age of 44. Musculoskeletal trauma occurs in 85% of these patients. In the USA, an annual count of 80,000 people sustain traumatic injuries leading to permanent disabilities. It's estimated that there are over 36 million emergency room visits each year due to musculoskeletal trauma, resulting in more than 442,850 deaths and 2 million hospital admissions. The causes of these injuries vary, including automotive collisions (head-on crush injuries, lateral impacts, ejections, auto vs. pedestrian), falls from rapid vertical deceleration, and gunshot wounds.

Assessing and Managing Musculoskeletal Injuries

First, assess and manage life-threatening hemorrhages and injuries that compromise the casualty's airway, breathing, and circulation. When evaluating a musculoskeletal extremity injury, take into account the mechanism of injury (MOI).

Envision potential primary injuries (the most apparent) and secondary injuries (the less apparent). The MOI offers vital insights into the nature and severity of musculoskeletal injuries. The existence of non-life-threatening musculoskeletal injuries could signal more severe underlying issues. Avoid letting musculoskeletal injuries divert your attention from identifying life-threatening conditions. Evaluate the following scenarios for musculoskeletal injuries:

- • Damage to the chest and lungs may accompany a forceful fracture of the humerus.
- • Rib fractures or bruising could indicate significant injuries to the thorax or upper abdomen.
- • The presence of facial lacerations or fractures might suggest a life-threatening condition. Categorize musculoskeletal injuries into one of three groups to prioritize care:

1. Multisystem, life-threatening trauma accompanied by non-life-threatening musculoskeletal trauma (e.g., life-threatening injuries with limb fractures).
2. Life-threatening musculoskeletal trauma (e.g., pelvic and femur fractures with critical blood loss).
3. Isolated, non-life-threatening musculoskeletal trauma (e.g., isolated limb fractures).

Fractures may be classified as open (compound) or closed long bone fractures. Open fractures occur when a high-energy event such as a vehicle accident, gunshot wound, or fall causes a long bone to break and its jagged edges to penetrate the soft tissue and skin. Closed fractures also result from high-energy impacts but do not break the skin. Open fractures carry a higher infection risk, while closed fractures can be life-threatening if the bone's jagged edges sever a major artery in the limb.

For instance, a femur fracture can lead to a loss of 1 to 2 liters of blood. Similarly, pelvic fractures can cause significant hemorrhage and may be fatal without prompt fracture detection. Fracture signs and symptoms vary with the injury's severity and typically include swelling, deformities, crepitus, restricted motion, pain, and loss of distal pulses. Avoid reproducing signs or symptoms unnecessarily, as this could displace clots or worsen the injury. Extremity fractures are usually apparent prehospital due to limb shortening, deformity, and swelling. Manage bleeding with direct pressure or a tourniquet when necessary.

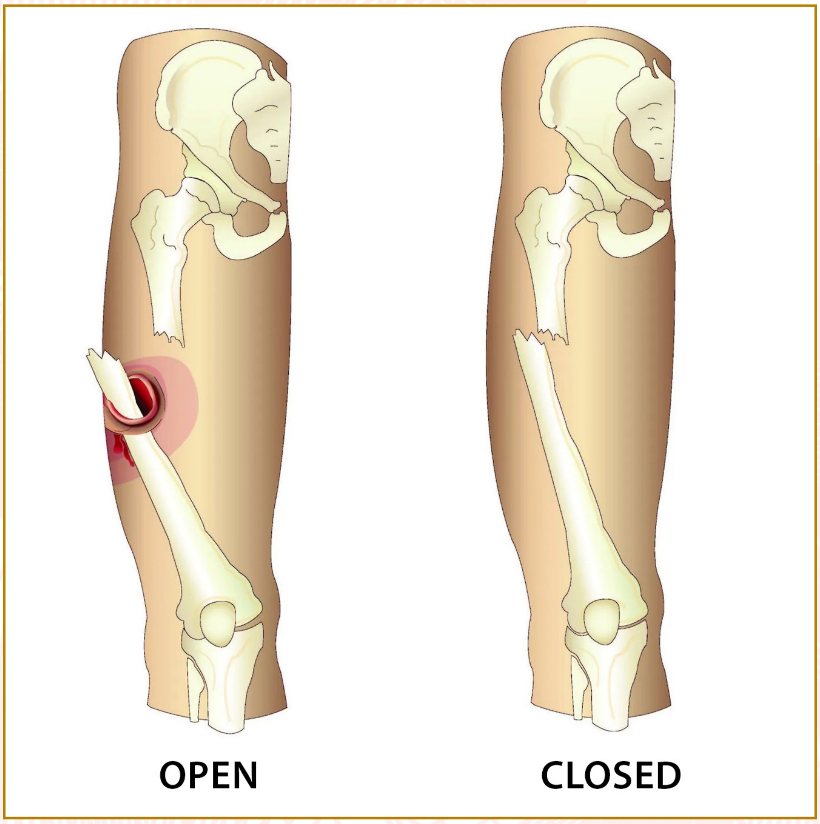


Figure 9.1 Types of fractures

Fractures should be stabilized or immobilized promptly. Perform a neurovascular pulse, motor, and sensory (PMS) assessment distal to the injury before and after splinting. Loss of motor and sensory functions often signifies nerve damage, while the absence of both functions and pulses suggests severe arterial and nerve injury.

Midshaft femoral fractures typically occur in younger individuals due to high-energy trauma, and they frequently accompany other traumatic injuries.

Muscle contractions may lead to the overlapping of bone ends. The clinical signs include pain, swelling, deformity, and limb shortening. To stabilize the fracture, apply gentle longitudinal pressure using a traction splint to realign the bone. The use of a traction splint can alleviate pain, prevent additional bone fragmentation, and reduce bleeding. Continue traction until the patient is transferred to a more advanced level of care to avoid additional injury to the limb.

For treating a pelvic fracture, use a pelvic binder, which immobilizes the pelvis and minimizes the risk of sharp bone fragments cutting major vessels within the pelvic area.

Secondary Assessment

It is necessary to acquire more details about the accident's mechanism, including the time elapsed since the injury occurred. Vital information about the patient can be sourced from pre-hospital personnel, which may include photographs from the accident scene that facilitate the assessment of vehicle damage, often referred to as "reading the wreckage."

Once the patient's airway is patent, breathing is adequate, and cardiovascular stability is achieved, a comprehensive assessment of the musculoskeletal system should be conducted, utilizing information from the physical examination and imaging studies. The secondary survey involves gathering detailed information about the patient's medical history, including allergies, previous illnesses or pregnancies, the last meal, and the events or environmental factors related to the injury. This is accompanied by a repeated head-to-toe physical examination and a reassessment of vital signs and the ABCs (airway, breathing, circulation).

History:

- Chief complaint.
- Mechanism of injury.
- History: OPQRST (Onset, Provoking/ alleviating factors, Quality/ Quantity, Radiation, Site, Timing)
- Constitutional symptoms- fever, night sweats, fatigue, wt. loss.
- Referred symptoms • AMPLE history (Allergies, Medications, past medical history, last eaten Events leading to)

Physical Examination:

- Look: SEADS (swelling, erythema, atrophy, deformity and skin changes).
- Move: Active and passive range of movement (ROM) for affected joint(s) and joints above & below.
- Neurovascular tests: Pulse, sensation, reflexes, power (0 to 5).

Investigations:

- Plain x-ray: AP, lateral and oblique
- It is very important to get correct views for proper diagnosis.

X-Ray rule of 2s:

- 2 sides= bilateral (comparison views in children when in doubt)
- 2 views= AP + lateral
- 2 joints= joint above + below

- 2 times= before and after reduction
- Blood: CBC, Grouping
- Aspiration: aspirate fluid from joint for analysis
- Ultrasound where appropriate

Principles of Emergency Care of Musculoskeletal Injuries

- Perform initial patient assessment- obtain relevant history and perform a "Focused PE" or "Rapid Trauma/Illness Survey" based on the nature or injury or illness.
- During a rapid trauma exam, apply a cervical collar if spine injury is suspected.
- After life-threatening conditions have been addressed, any patient with a swollen or deformed extremity must be splintedو If an initial assessment reveals the patient is unstable, managing extremity injuries becomes a low priority.

Evaluating soft tissue injuries necessitates a thorough knowledge of the anatomy of the affected region. For every instance of penetrating trauma, a clinical evaluation of all underlying structures in the wound area is essential. Additionally, when assessing the extent of the damage, it is important to take into account the patient's posture at the time of the injury.

Soft Tissue Injuries Assessment

Evaluating sensation soon after an injury can be challenging. Patients might report feeling sensation even when further examination reveals that the relevant nerve is severed. To assess, use a blunt instrument, such as a contoured paperclip, for simple touch and two-point discrimination tests. It's better to compare the sensation to the opposite side rather than asking if it feels normal or present.

The region of altered sensation should be delineated and documented. While motor function assessment can be more exact, it also demands knowledge of anatomy. Should the patient's history, clinical signs, and symptoms indicate a nerve injury, a referral for surgical exploration and potential nerve repair is necessary, to be performed in an operating room.

Evaluating vascular damage involves assessing skin pallor, capillary refill time, skin temperature, turgor, and peripheral pulses. Palpation can determine the latter, but in cases of uncertainty, a Doppler device is useful for locating the pulse, estimating pressures, and making comparisons to the unaffected side. It is important to note that vascular injuries can still occur despite the presence of distal pulses, and muscles become more susceptible to damage when ischemia surpasses 120 minutes. Thus, prompt and repeated reassessment is essential when vascular injury is suspected.

When an injury to a major limb artery is suspected, it is crucial to seek an urgent vascular assessment. In cases of direct vascular trauma from penetrating injuries, the necessity for referral is typically clear. However, in instances of blunt trauma, clinicians should be highly vigilant and consult a specialist if there's any uncertainty. The goal is to minimize warm ischemic time to lessen tissue damage, aiming for less than five hours. Such patients will likely need angiography, either preoperatively or intraoperatively.

Tendon injuries are common in limb lacerations, especially in the wrist and hand. A thorough understanding of anatomy and a systematic examination method for each body area are crucial. Wound inspection alone can be deceptive, as retracted tendon ends may not be visible. Suspected tendon injuries necessitate a referral for formal exploration.

Analgesic Pain Management

Once the injury is splinted and stabilized, the patient should experience significant pain relief. Analgesics are advised for isolated joint and limb injuries, except for patients with contraindications such as unconsciousness, respiratory compromise, altered mental status, hypoperfusion, or known allergies to morphine. It is always recommended to use the least sedating pain control medication first, as long as it is effective.

Additionally, oral or IV analgesics are considered a standard of care, whereas peripheral nerve blocks may be recommended for certain injuries. In cases of major trauma, oral, subcutaneous, and intramuscular routes are typically avoided because of their reduced efficacy.

Management of Specific Injuries

Arterial Hemorrhage

During the primary survey, bleeding must be managed and a vascular surgery consultation should be obtained. If bleeding is uncontrolled, an emergency progression to the operating room for repair, bypass, or embolization is necessary, especially if the injured vessel is expendable. Such injuries may necessitate intraoperative angiography.

An uninjured leg should also be prepared for a potential saphenous vein graft harvest. Should bleeding be contained and the patient stabilized, vascular surgery may request a CTA before moving to the operating room or angiography suite to characterize better and localize the injury, a decision often dependent on the injury's severity and the elapsed time since the injury occurred.

Traumatic Rhabdomyolysis

For patients with significant crush or ischemic injuries, monitoring for the development of rhabdomyolysis is crucial. The classic symptoms and signs to watch for include muscle pain, weakness, fatigue, confusion, nausea or vomiting, muscle edema, dark or tea-colored urine, and irregular heartbeat or palpitations.

Routine laboratory work, including electrolytes (Na, Cl, K, HCO_3, Mg, Ca, and PO_4), creatinine, urea, creatinine kinase, and myoglobin, is crucial for diagnosing and monitoring complications. A creatinine kinase (CK) level greater than 1000 is commonly cited for diagnosis, while levels above 5000 are linked with acute kidney injury and potential renal damage. Urinalysis can provide additional supporting evidence.

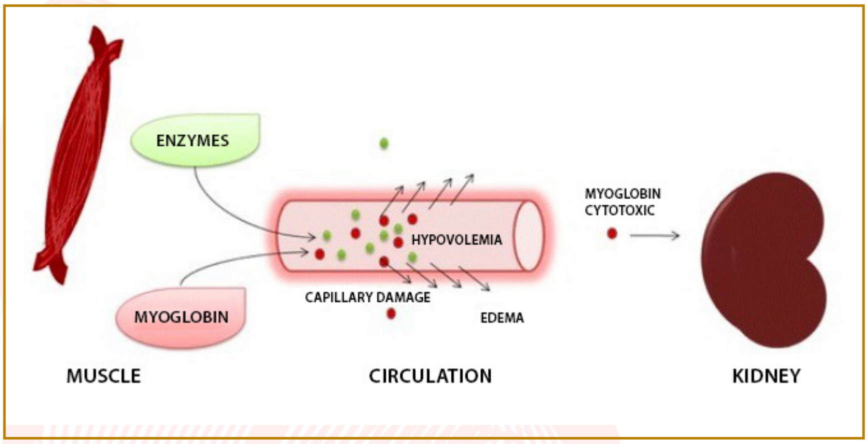


Figure 9.2 Traumatic Rhabdomyolysis

In severe cases, an ECG and possibly telemetry are essential to monitor cardiac arrhythmias related to electrolyte imbalances. Management begins with aggressive fluid resuscitation to maximize renal clearance and protect renal function, as well as to alkalize the urine to guard against myoglobinuria and hyperuricosuria.

The goal is a urine output of 100-300 mL/hr, achieved by administering normal saline at a rate of 0.5-1.5 L/hr. Patients with pre-existing cardiovascular disease may require less aggressive fluid resuscitation to avoid the risk of fluid overload.

Sodium bicarbonate may be used to further alkalize the urine if necessary. Once there is an improvement in CK and electrolyte levels, diuresis with mannitol or furosemide may be considered. Any electrolyte or acid-base imbalances should be corrected. For severe rhabdomyolysis patients with hyperkalemia and acute kidney failure unresponsive to aggressive fluid resuscitation, hemodialysis is recommended in the intensive care unit.

Vascular Injury/Avascular Limb

Ensure arterial hemorrhage is excluded before proceeding. Immediate operative treatment is absolutely indicated for any hard signs of vascular injury or an avascular limb that persists despite reduction or realignment. Reduction and immobilization of the limb, if fractured or dislocated, should precede any further management or work-up.

Early consultation with vascular surgery is advised. However, vascular injuries to the forearm or hand often involve concurrent tendon and/or nerve injuries and are typically managed by plastic surgeons. The most critical factor in management is the time to revascularization; the goal is typically within 6 hours, as irreversible damage to nerves and muscles may begin after this period.

Timing and outcomes can vary based on several factors, including pre existing conditions and collateral blood flow. If the patient is stable, the timing permits, and injury localization is necessary, a CTA with lower extremity run-offs is recommended.

In cases where a patient requires urgent transfer to the operating room, on-table angiography may be considered following the achievement of vascular control, especially in instances of ongoing distal malperfusion. Treatment options for vascular injuries encompass primary repair, or alternatively, repair with a bypass or patch, typically utilizing the great saphenous vein.

Depending on the patient's condition and concurrent major injuries, the placement of a temporary shunt might be an option. When vascular injury occurs alongside a fracture or dislocation, stabilizing the affected area is crucial to safeguard the vascular repair. If the patient's condition and timing permit, orthopedic surgeons generally opt to place an external fixator before proceeding with vascular repair.

Further diagnostic work-up is indicated if a vascular injury is suspected without hard signs, and if the timing and patient stability permit. This typically includes a CT angiography, but conventional angiography or duplex ultrasound may also be utilized. If imaging reveals extravasation, an acute pulsatile hematoma, early pseudoaneurysm, occlusion, or an arteriovenous fistula, emergency surgery is warranted, with options as previously mentioned.

Depending on the injury's location and the patient's condition, the vascular surgeon may consider endovascular treatments such as coil embolization or stenting. Some vascular injuries may be managed non-operatively with monitoring and ongoing clinical exams, provided there is perfusion with normal clinical findings and a palpable pulse distally. This decision rests with the vascular surgeon.

If an intimal defect is present, an ankle-brachial index (ABI) should be conducted or repeated, as a palpable pulse can be present yet misleading. If the ABI is less than 0.9 in the affected limb, operative intervention is typically necessary. In nonoperative cases, thromboprophylaxis may be initiated unless contraindicated by other injuries.

Traumatic Amputation/Mangled Extremity

Pre-operative management principles may necessitate consultations from orthopedic, plastic, and vascular surgery specialists, depending on the injury's location. This includes controlling hemorrhage, debriding gross contamination, and applying a moist sterile dressing. It is crucial to ensure that the dressing does not induce compartment syndrome.

Excessive scrubbing or rinsing should be avoided as it may dislodge clots and lead to further bleeding. For an amputated part, rinse and wrap it in saline-moistened, sterile gauze, then place it in a waterproof bag and submerge it in cool liquid at 4-10°C or on ice.

Obtaining an accurate timeline regarding injury and ischemic time is essential, if possible. AP and lateral radiographs of the injured extremity should be taken. If replantation is considered, the amputated part must also be x-rayed. Tetanus vaccination and antibiotics are recommended (refer to the open fracture section). Definitive management options include limb salvage, revision amputation, or replantation.

However, reconstruction was associated with increased complications and rehospitalizations, while amputation led to higher healthcare costs. No extremity severity score was correlated with predicting outcomes. An insensate foot was not an indication for amputation, and smoking was associated with increased rates of non-union and infection.

Risk factors for amputation include Gustilo IIIC injuries, anatomical transection of the sciatic or tibial nerve, or two of the three upper extremity nerves. Other factors are prolonged ischemia/muscle necrosis, crush or destructive soft tissue injury, high degree of contamination, multiple or severely comminuted fractures/segmental bone loss, old age/severe comorbidities, and lower versus upper extremity involvement. The apparent futility of revascularization or failed revascularization also contributes.

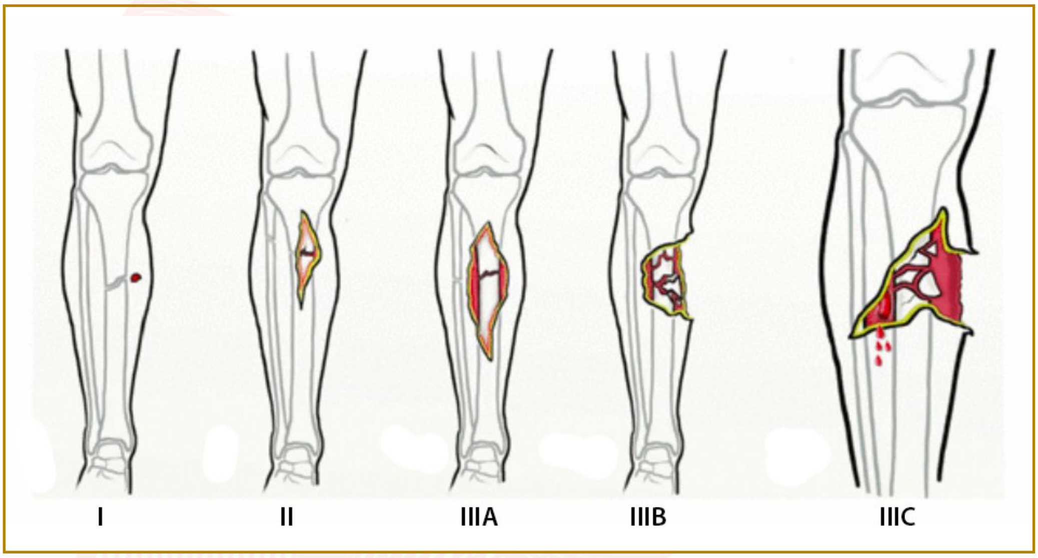


Figure 9.3 Gustilo open fracture classification

For traumatic amputations, indications for replantation include absolute and relative conditions: Absolute indications encompass thumb amputations at any level, multiple digit amputations, amputations in children, hand amputations at palm, wrist, or proximal to wrist, and guillotine amputations. Relative indications include single digit amputation distal to FDS insertion (Zone 1), ring avulsions, and amputations through or above the elbow.

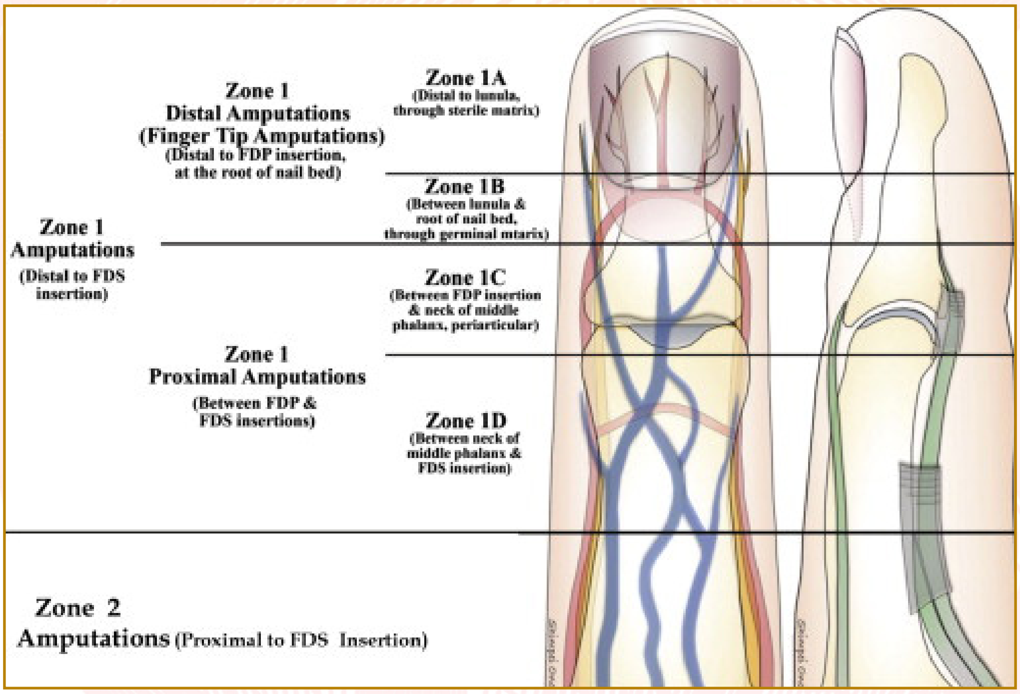


Figure 9.4 Finger Amputation and Replantation

Nerve Injury

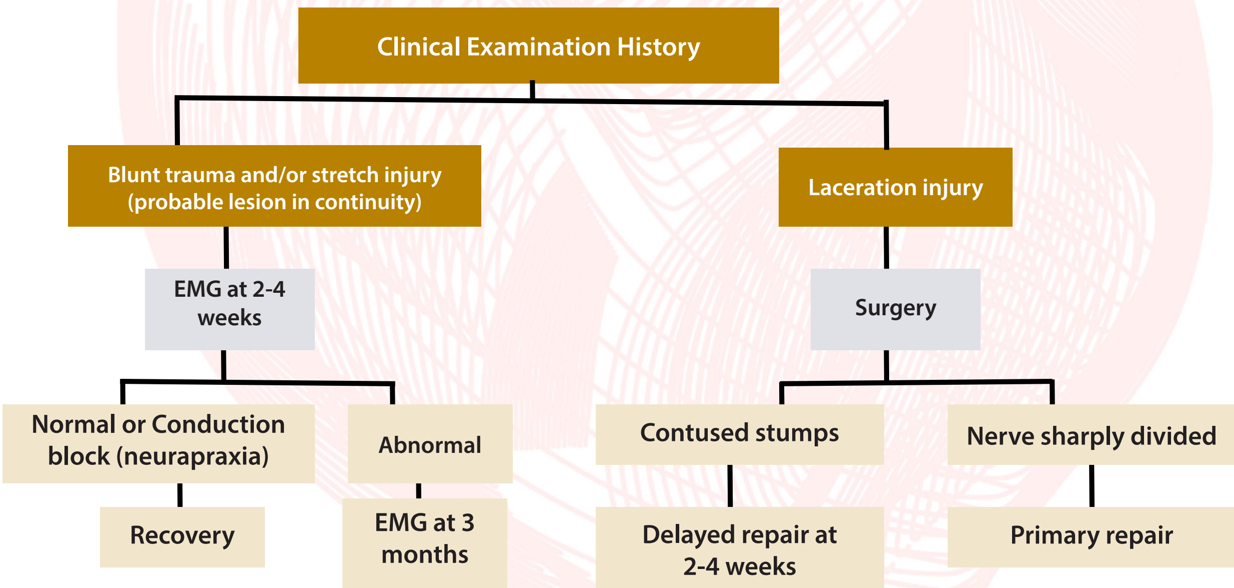
The initial emergency management of a nerve injury involves diagnosis and documentation, followed by the reduction and immobilization of any associated fracture or dislocation as needed. It is crucial to assess and document the neurovascular status after reduction.

Emergent operative management may include consulting plastic surgery for surgical exploration. Indications for this include penetrating trauma that results in a complete peripheral nerve deficit—excluding low-energy gunshot injuries—and progressive defects. Surgery may also be indicated for other reasons, such as debridement, vascular repair, or open skeletal fixation. If the wound is clean, with a good vascular supply, adequate soft tissue coverage, and sufficient skeletal stabilization, primary nerve repair or reconstruction may be undertaken.

Repair is feasible if healthy nerve ends are present (before or after debridement) and the repair can be done without tension. If the repair would be too tense, reconstruction may be accomplished with conduits for defects less than 3 cm or autograft nerve for larger defects. If autografting is an option, prepare the donor site on the arm (antebrachial cutaneous) or leg (sural) for nerve harvesting. If wounds are contaminated, or if additional soft tissue coverage or skeletal fixation is required, nerve ends should be tagged to healthy tissue to prevent retraction. It is advisable to return within three weeks for delayed repair or reconstruction for optimal outcomes.

Initial emergency management of a Nerve Injury involves diagnosis and documentation, followed by reduction and immobilization of any associated fracture or dislocation. The neurovascular status post-reduction should always be assessed and recorded.

Emergency operative management may include a plastic surgery consultation for surgical exploration. Indications for this include penetrating trauma resulting in a complete peripheral nerve deficit, excluding low-energy gunshot injuries, progressive defects, or if surgery is already being performed for another reason such as debridement, vascular repair, or open skeletal fixation. If there is a clean wound with a good vascular supply, adequate soft tissue coverage, and sufficient skeletal fixation, then primary nerve repair or reconstruction can be undertaken.



Algorithm 9.1 Nerve Injuries Algorithm
EMG: Electromyography

Open fractures

Open fractures are fractures that have a connection to a break in the skin. There may be minor differences between superficial abrasions and a true open fracture. Wounds that persistently bleed or expose fat tissue are indicators of an open fracture. Probing the wound with a sterile instrument can aid in diagnosis. Administering antibiotics early, ideally within three hours, can reduce the risk of infection.

Tetanus prophylaxis is also important to administer according to the chart below

Table 9.1 Tetanus vaccine administration chart

Vaccination Status	Clean, Minor Wound (Type I)	Contaminated Wound (Type II or III)
Vaccination Complete (≥3 doses)	Give Vaccine only	Give Vaccine and Immunoglobulin
known or Incomplete Vaccination History (<3 doses)	Give Vaccine if >10 years since last dose	Give Vaccine if >5 years since last dose

All open fractures should be irrigated with normal saline to remove gross contamination, then covered with a sterile, saline-moistened, loosely applied dressing. The limb must be realigned and splinted. Further reduction might be necessary by orthopedic specialists if there is a fracture dislocation that remains incompletely reduced after realignment, and the patient is not immediately headed for surgery.

For operative management, an orthopedics consultation is required, and possibly a plastics consultation if there is significant soft tissue damage. Orthopedics typically consults plastics after the initial debridement. Surgery is recommended for all open fractures, although the timing remains debated. Type I and II open fractures should have surgery within 24 hours, while Type III open fractures should be operated on within 8 hours. If the patient is already scheduled for another surgery, the open fracture should be addressed during the same procedure. Surgical principles involve extending the wound in line with the limb in a Z-pattern, debriding devitalized tissue (including bone fragments), and performing low-pressure saline irrigation, followed by either external or definitive fixation, depending on the patient's condition and the wound's contamination level. It is also important to consider the surgical approach needed for definitive treatment if a temporary procedure is being performed.

Wound closure should be performed when possible, provided the wound is clean. Negative pressure wound therapy (NPWT) may be employed if closure is not feasible. In cases of contamination, the patient should be brought back to the operating room within 48 hours for further debridement. For significant soft-tissue loss requiring additional coverage, consultation with a plastic surgeon for early soft tissue coverage, in accordance with the reconstructive ladder, is advisable. There is an increased risk of infection if the wound is not covered within seven days.

Compartment syndrome

Compartment syndrome is a serious condition that, if undiagnosed, can lead to significant morbidity. Early symptoms include disproportionate pain, paresthesia, tense compartments, and pain upon passive stretching of the affected area. Advanced symptoms may manifest as paralysis and absence of peripheral pulses. In children, symptoms may present as increased anxiety, restlessness, and a greater need for analgesia.

Orthopedic consultation is advised if compartment syndrome is suspected. Any cast should be split or any splint/dressing removed entirely. The affected limb should be elevated above heart level.

Diagnosis is typically based on physical examination, but compartment pressure measurement may be necessary in certain cases, such as with polytrauma patients, those who are comatose or unreliable, those with nerve injuries or regional anesthesia, or when history and examination findings are inconclusive. This measurement is done using a device with a needle inserted into the affected compartments.

The diagnostic criteria for compartment pressure have evolved; while an absolute pressure greater than 30 mmHg was once standard, a differential pressure (ΔP) greater than 30 mmHg is now also considered diagnostic, where ΔP equals diastolic blood pressure minus intramuscular pressure. Both criteria are currently accepted.

Once diagnosed, the definitive treatment is emergent fasciotomies of all compartments in the affected limb segment. This procedure should be readily performed. Post-operatively, wounds should remain open and be covered with negative pressure wound therapy (NPWT) or wet-to-dry dressings.

Reassessment and possible debridement should occur within 48 hours, followed by delayed closure. If closure is not feasible, consultation with a plastic surgeon for split-thickness skin grafts may be necessary.

Closed fractures and dislocations

Emergency management of closed fractures and dislocations includes reduction, immobilization, and orthopedic consultation. Some fractures may require temporary skeletal or skin traction, such as acetabular fractures with dislocating hips or pediatric femur fractures. Definitive management may be non-operative or operative, depending on the fracture type.

Emergency operative indications typically include fractures/dislocations with compartment syndrome, such as tibial shaft fractures, or with vascular injury, such as knee dislocations or supracondylar humerus fractures, if not resolved with closed reduction. Also included are fractures/dislocations with skin compromise, like displaced tongue-type calcaneus fractures, and irreducible dislocations or fracture dislocations, such as hip dislocations.

Other closed fractures or dislocations can usually be realigned, reduced, and splinted until the patient is stable. Subsequent to stabilization, operative treatment may be necessary. Hand fractures, though often overlooked, are crucial to manage properly with reduction, splinting, and early plastic surgery consultation. Damage Control Orthopedics (DCO) involves postponing definitive orthopedic treatment in an unstable patient until their physiological condition improves.

Reduction and external fixation are typically utilized in emergencies rather than as definitive treatments.

Contusions, Hematomas, and Morel-Lavallée Lesions

Contusions and hematomas are usually self-limiting and can be managed conservatively, provided they are not rapidly expanding, as they may indicate underlying pathology.

A Morel-Lavallée Lesion (MLL) arises from a high-energy shearing injury that separates the subcutaneous fat from the deep fascia, creating a potential space. This space can fill with blood, lymph, and fatty debris, which is eventually replaced by serosanguinous fluid. This fluid can act as a medium for bacterial growth, as these lesions may become colonized in up to 50% of cases. There is a risk of surgical site infections if surgery is performed in proximity to the lesion.

The most common locations for lesions include the greater trochanter/hip (30%), gluteal region (6%), thigh (20%), lumbosacral area (3%), pelvis (19%), calf/lower leg (2%), knee (16%), and abdominal area (1%). These lesions are often minimally symptomatic and can be overlooked due to other distracting injuries, thus a high index of suspicion is necessary for diagnosis.

Diagnosis is usually established through physical examination, and imaging (CT or ultrasound) helps to determine the lesion's size for management. Small lesions (< 50 cm^3), distant from a surgical site, can generally be managed with compression or percutaneous drainage. However, percutaneous drainage should be considered carefully as some studies suggest higher recurrence rates compared to non-operative or surgical management. Larger lesions (> 50 cm^3) typically require surgical irrigation and debridement with negative pressure wound therapy (NPWT) or drain insertion, as they have a higher risk of treatment failure with conservative methods, and an increased risk of colonization and infection. While surgery can be an effective treatment, it may compromise the subdermal vascular plexus, which is the sole blood supply remaining for the superficial tissue.

Figure 9.5 negative pressure wound therapy (NPWT)

Soft Tissue Wounds, Tendon Lacerations, & Traumatic Arthrotomy

Soft tissue wounds are generally treated nonoperatively through primary closure, delayed primary closure, or secondary intention healing. Antibiotics and tetanus prophylaxis should be considered.

For facial lacerations, cosmetic outcomes must be considered once the patient is stable. If the wound is too large for these methods, plastic surgery consultation is advised for operative coverage following the reconstructive ladder principles. A high suspicion for tendon laceration is necessary for wounds over the distal forearm, leg, foot, or hand, as tendons are superficial and prone to injury.

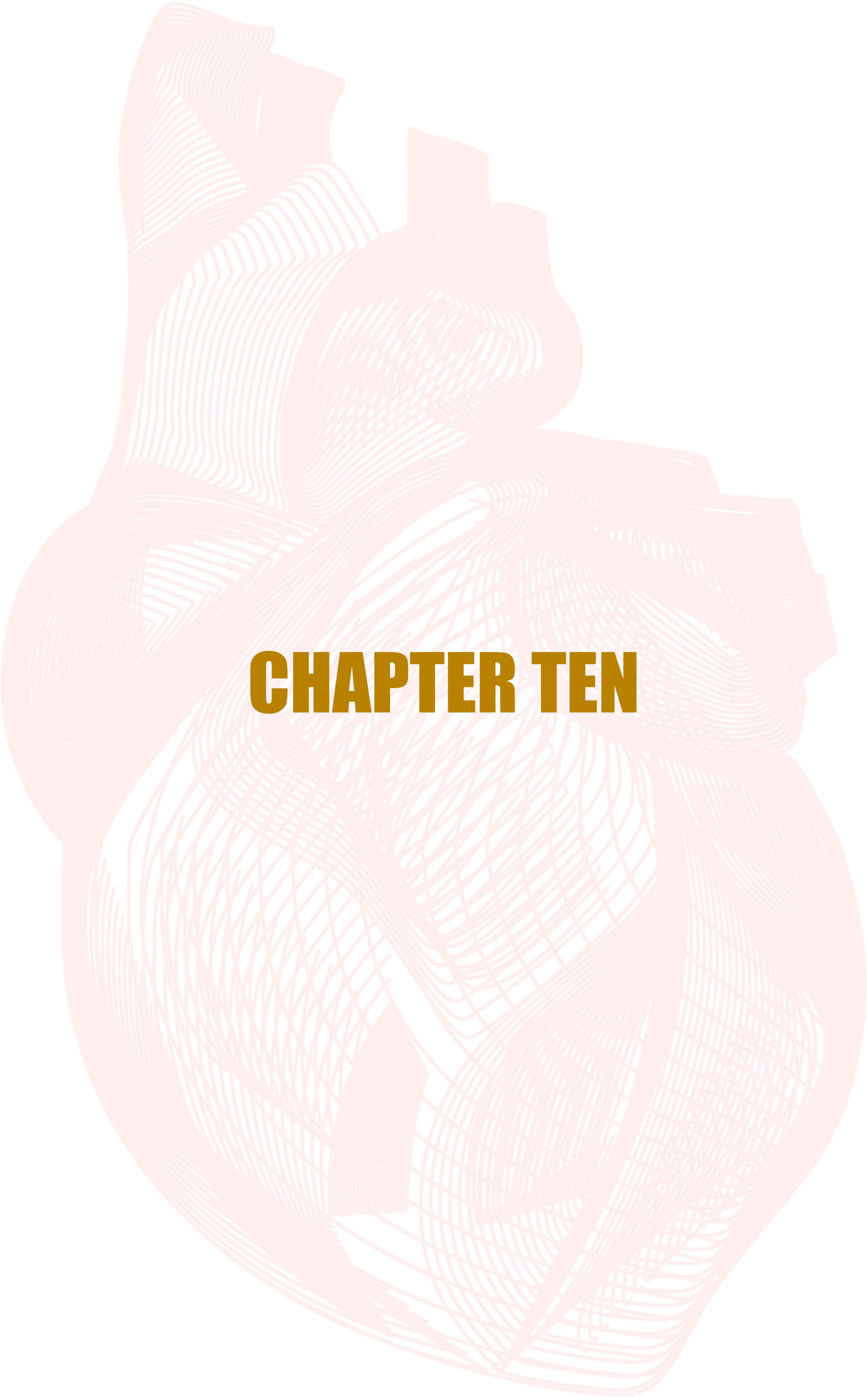
Diagnosis relies on physical examination findings, and management includes antibiotics, tetanus prophylaxis, surgical debridement, and repair. Traumatic arthrotomy should be suspected with any periarticular soft tissue wound due to the high risk of infection from intra-articular communication with the external environment.

Diagnosis can be challenging and subtle. A CT Scan is the most specific and sensitive test, identifying intra articular air.

The Saline Load Test involves an intraarticular injection of saline, with or without methylene blue, to check for fluid leakage from the capsule. Oral antibiotics and proper local wound care are necessary, though not as sensitive or specific as a CT scan.

Different joints require varying volumes for 95% sensitivity: 155 cc for the knee, 40 cc for the elbow, and 30 cc for the ankle. An X-ray is used to confirm that a periarticular fracture is not overlooked. Management includes prompt antibiotic treatment, followed by urgent surgical exploration, irrigation, and debridement.

The typical antibiotic regimen is cefazolin 2 g IV every 8 hours pre-operatively and for 24 hours post-operatively, then cephalexin 500 mg orally four times daily for 5 days. The most recent regimen recommends piperacillin/tazobactam 3.375 g IV every 6 hours for 48 hours, followed by amoxicillin/clavulanate 875 mg orally twice daily for 5 days.



CHAPTER TEN

Trauma in pregnancy and domestic violence

Learning Objectives:

At the end of this chapter, the reader will be able to:

- Understand the anatomical changes during pregnancy.
- Approach trauma pregnant victims following a systematic approach (primary and secondary) evaluation.
- Know how to manage trauma victims during pregnancy.

Introduction:

Injuries during pregnancy, whether due to accidents or domestic violence, can significantly affect both the mother and the fetus.

Trauma during pregnancy is rare but is the leading cause of non-obstetric death. It poses unique challenges for the resuscitation team because they must care for both the mother and the fetus. The anatomical and physiological changes in pregnancy affect the injury patterns and the patient's response to treatment. On the other hand, domestic violence is unfortunately very common, often goes undiagnosed, and without proper intervention, can be deadly.

The best initial treatment for the fetus is to ensure optimal resuscitation of the mother. Early consultation with a qualified surgeon and obstetrician is crucial for evaluating pregnant trauma patients. If these specialists are not available, consider early transfer to a trauma center.

Anatomical changes during pregnancy

In the first 12 weeks of pregnancy, the uterus is well-protected within the pelvis. By the second trimester, it rises but remains shielded by its muscular walls and amniotic fluid. In the third trimester, as the uterus enlarges and its walls thin, it becomes more vulnerable, with the diaphragm and bowel displaced into the thorax. Near term, the descent of the fetal head can decrease fundal height, but engaged fetal heads increase the risk of serious fetal injury in maternal pelvic fractures.

The placenta, unlike the elastic uterus, can tear from shear forces, leading to placental abruption even with minor trauma. This must be considered when treating pregnant patients.

In late pregnancy, lower chest and upper abdominal injuries can affect the gastrointestinal tract. The uterus often protects the mother by absorbing impact, resulting in better maternal outcomes, but the fetus is at higher risk. Gunshot wounds to the uterus have a maternal mortality rate of 7-10% but a fetal death rate of about 70%.

Primary Evaluation and Resuscitation

The primary survey and resuscitation for pregnant trauma patients follow the same principles of non-pregnant lady but require adjustments due to pregnancy-related anatomical and physiological changes.

To improve outcomes for both mother and fetus, prioritize assessing and resuscitating the mother, followed by fetal assessment before performing a secondary survey on the mother.

The key adaptations are summarized below.

Airway

Pregnancy increases the risk of gastric content inhalation, particularly from the second trimester. To prevent this, secure the airway early with a cuffed tracheal tube, noting the higher incidence of difficult intubation. Due to decreased functional residual capacity and increased oxygen consumption, ensure thorough pre-oxygenation before administering hypnotics and neuromuscular blockers. This should be done by trained personnel. Alternative airway devices should be available for difficult intubations, though they do not prevent aspiration and should be replaced with a tracheal tube when possible.

Breathing and Ventilation

Pregnant patients typically hyperventilate due to increased tidal volume, resulting in a PaCO2 of 30-34 mmHg. They desaturate faster than non-pregnant women, so provide supplemental oxygen to all pregnant trauma patients.

Circulation and Control of Hemorrhage

Pregnancy-induced cardiovascular changes complicate trauma management. Heart rate increases throughout pregnancy, peaking in the third trimester at 10-15 beats/min above baseline. Blood pressure drops by 5-15 mmHg in the second trimester but returns to normal by term. Blood volume rises by 40-50%, causing physiological anemia, with a hematocrit of 30-35% in late pregnancy. Supine positioning can cause aortocaval compression, reducing venous return and cardiac output, and impairing fetal blood flow. Prevent this with manual uterine displacement or a 15-degree left lateral tilt.

Pregnant trauma patients can mask hypovolemia until significant blood loss occurs. Blood pressure drops can cause placental vasoconstriction and reduced fetal oxygenation. Catecholamine-sensitive uterine vessels exacerbate this. Early signs of maternal physiological changes should alert the team to potential fetal compromise. Administer anti-D immunoglobulin early in Rh-negative women with uterine bleeding. Consider uterine rupture in cases of shock, identified by abdominal tenderness, rigidity, abnormal fetal lie, and palpable fetal parts.

Disability

Trauma may result from a seizure due to pregnancy-related hypertensive disease (eclampsia). Post-seizure reduced consciousness can be mistaken for a head injury. Perform a urine dipstick test for proteinuria with hypertension and edema will help to diagnose it. Seek skilled obstetric help as needed.

Exposure

Conduct a full examination, ensuring to prevent hypothermia. Urogenital tract bleeding might be first noticed at this stage.

Investigations

Use sonography and CT scanning as indicated, similar to non-pregnant trauma patients.

Secondary Evaluation

After primary evaluation and resuscitation, a systematic secondary survey is conducted. Additionally, prompt obstetric consultation and fetal heart sound assessment are crucial. Doppler can detect fetal heart sounds as early as 10 weeks, and for continuous fetal monitoring cardiotocographic monitoring is used between 20-24 weeks. Normal fetal heart rate ranges from 120-160 beats per minute; deviations may indicate fetal distress.

Carefully examine the abdomen, noting tenderness and guarding, despite potential difficulty due to the thinning abdominal wall and stretched peritoneal membrane. Palpate for fetal movements and check for uterine contractions. Measure the height of the uterus to estimate gestational age, which typically corresponds in centimeters to the number of weeks of gestation.

An obstetrician should perform a vaginal examination to assess fetal position, vaginal bleeding, amniotic fluid presence, and cervical dilation or effacement. Vaginal bleeding occurs in up to 70% of placental abruption cases, along with uterine tenderness and contractions.

The duration of electronic fetal monitoring after trauma is debated. If the initial assessment shows more than six contractions per hour, abdominal or uterine tenderness, ruptured membranes, hypotension, or vaginal bleeding, continue monitoring for at least 24 hours. If these signs are absent and abdominal sonography is normal, discharge may be considered after four hours. Signs of placental abruption and fetal distress in a viable fetus require immediate operative delivery.

Feto-Maternal Hemorrhage

Feto-maternal hemorrhage, occurring in 8-30% of pregnant trauma cases, involves blood transfer from the fetus to the mother, risking sensitization of an Rh-negative mother by an Rh-positive fetus. To prevent this, administer 300 micrograms of anti-D immunoglobulin to all Rh-negative pregnant women within 72 hours of injury, unless the trauma is distant from the abdomen.

Perimortem Cesarean Section

In trauma-related cardiac arrests, if resuscitation fails within 5 minutes, delivering the fetus (if over 20 weeks) may aid in effective CPR and circulation restoration in the mother. This decision must involve close collaboration with an obstetrician.

Unique Injury Patterns:

Blunt Trauma:

While motor vehicle collisions (MVC) are the most common cause of serious blunt trauma during pregnancy, assaults, abuse, and falls also occur frequently. Beyond the risk of maternal mortality from blunt trauma, the fetus faces significant dangers, including placental abruption, uterine rupture, and rupture of membranes. The primary risk factor for adverse outcomes during MVC is the improper use of seat belts; proper usage can prevent impact with the steering wheel in both front and rear collisions.

Placental Abruption:

- Occurs in 2 to 4% of minor injuries.
- Occurs in up to 50% of major traumas.
- Maternal mortality from abruption is less than 1%, but fetal mortality ranges from 20 to 35%.
- Separation occurs as the inelastic placenta detaches from the elastic uterus during sudden uterine deformation.
- Abruption can happen with minimal or no visible injury to the abdominal wall.
- The predictability of abruption is not correlated with the severity of maternal injury or placental position.
- Abruption may present with vaginal bleeding or be concealed, with no external bleeding.
- Clinical signs of abruption include:
- Vaginal bleeding
- Abdominal pain
- Uterine tenderness/contractions
- Leakage of amniotic fluid
- Maternal hypovolemia
- An abnormally large uterus for gestational age
- Changes in fetal heart rate
- Post-trauma vaginal bleeding is a grave sign, often indicating placental separation.

Diagnostic Tests:

Transabdominal ultrasound is less than 50% accurate. Cardiotocographic (fetal) monitoring is more sensitive in detecting placental abruption through signs of fetal distress.

Diagnosis of abruption is primarily clinical and often becomes apparent within hours after trauma. Fetal monitoring is recommended to commence in the resuscitation room and continue for at least 4 hours post-trauma. Imaging should not delay the management of placental abruption if clinically suspected.

Uterine Rupture:

This condition is characterized by a defect in the gravid uterine wall, with 75% of cases involving the uterine fundus. It may result in serosal hemorrhage, avulsion of uterine vasculature with hemorrhage, or complete disruption of the myometrial wall, leading to the extrusion of the fetus, placenta, or umbilical cord into the abdominal cavity.

Clinically, it presents with uterine tenderness, vaginal bleeding, non-reassuring fetal heart rate patterns, rapid onset of maternal hypovolemic shock, palpable fetal parts on abdominal examination, and signs of peritoneal irritation such as distention, rebound tenderness, guarding, and rigidity.Management involves urgent laparotomy to control bleeding and aid resuscitation.

Penetrating Trauma:

The management of penetrating injuries depends on the entry location and gestational age. Fetal mortality can reach up to 60% in cases of penetrating trauma. Maternal outcomes are generally better during pregnancy compared to non-pregnant states, possibly due to anatomical shifts during pregnancy, like the upward displacement of visceral organs by the enlarging uterus. Thus, upper abdominal penetrating trauma is more likely to injure maternal bowel, whereas lower abdominal trauma tends to harm the uterus or fetus.

While immediate surgical exploration is typically the preferred management in non-pregnant patients, this is not always the case for pregnant patients. The decision to proceed with surgery depends on several factors: the injury's location, uterine size, and maternal and fetal vital signs. The likelihood of visceral injuries is reduced when the entry site is anterior and below the uterine fundus, and wounds that do not penetrate beyond the abdominal wall may be managed non-operatively.

Exploratory laparotomy is warranted when there is any sign of peritoneal penetration, especially if there is suspicion of intraperitoneal hemorrhage or bowel perforation. Tetanus prophylaxis is considered safe during pregnancy, with indications similar to those in non-pregnant individuals. Peritoneal lavage is also possible during pregnancy, preferably using an open technique after a nasogastric tube and a Foley catheter have been placed.

Pelvic fractures do not necessitate cesarean delivery. Most women are able to safely attempt vaginal birth after a pelvic fracture, including those occurring in the third trimester. When thoracostomy is necessary during pregnancy, it is advised to place the tube at least one or two intercostal spaces above the standard fifth intercostal space to prevent accidental abdominal insertion.

Domestic Violence

Domestic violence is prevalent. A Swiss survey found a 20% incidence among 1500 women, and a UK study showed that 25% of women experienced some form of domestic violence. Other data indicate that up to one-third of women face physical abuse, sexual coercion, or other forms of abuse in their lifetimes.

Diagnosis and Management

Given the prevalence of this issue, trauma team members will encounter it regularly in practice. However, due to the associated shame and guilt, under-diagnosis is common. Therefore, maintaining a high level of clinical suspicion is crucial. Indicators suggesting non-accidental injuries include:

- Injuries inconsistent with the provided explanation
- Frequent Emergency Department visits
- Self-blame for the injuries
- Delayed seeking of medical care
- Low self-esteem, signs of depression, or self-harm
- A partner who insists on always being present
- Substance abuse
- Inappropriate concern about the injuries

While identifying victims of domestic violence is essential, immediate care for their injuries takes precedence. Once the patient's injuries are addressed, a team member should screen for signs of violence and ensure referral to appropriate local authorities, following local protocols.

CHAPTER ELEVEN

Burn

Learning Objectives:

At the end of this chapter, the reader will be able to:

- Assess the degree and seriousness of the injury.
- Recognize and prioritize treatment requirements.
- Ensure airway management and assist with ventilation.
- Start, observe, and modify fluid resuscitation as needed.
- Utilize appropriate techniques for physiological monitoring.

Introduction

A burn is defined as damage to the skin and underlying tissues caused by heat, chemicals, or electrical sources. According to the World Health Organization (WHO), nearly 11 million individuals experienced such injuries worldwide in 2004. Each year, approximately 45,000 people are hospitalized due to burns.

In the U.S., it is estimated that 3,200 individuals die annually from fire and burn incidents, predominantly due to residential fires (2,845), with around 180,000 deaths occurring globally, primarily in low- and middle-income countries. Additional causes include accidents involving vehicles and aircraft, electrical exposures, and contact with hot liquids, chemicals, or other substances.

A systematic review in Saudi Arabia indicated that burns disproportionately affect males compared to females (58.6% vs. 41.4%, respectively). This study also highlighted that 25% of those affected were under 2 years of age, while 50% were aged 16 years and older, suggesting a significant occurrence of burn injuries among children. The overall weighted mortality rate from severe burns in Saudi Arabia has been reported at 5.9%, while a burn unit in the Jizan region recorded a rate of 16.7%.

About 75% of these fatalities occur at the site of the incident or during early transport, with most related to smoke inhalation. The leading cause of fire-related deaths in the United States is fires started by smoking materials, particularly cigarettes.

Effective initial treatment for patients with severe burns is crucial for positive clinical outcomes. Early detection and management of airway and breathing issues can prevent premature fatalities. Starting appropriate fluid resuscitation is vital to avoid serious complications such as organ failure and infection. Additionally, recognizing and addressing related injuries is important.

Primary Survey

The initial evaluation of a burn patient mirrors that of other trauma cases: prioritize the recognition and treatment of life-threatening and limb-threatening injuries first. Many burn patients also sustain accompanying traumatic injuries. First responders must remain vigilant and not allow the presence of burns to divert attention from more critical injuries.

The primary assessment includes the following components:

A. Airway Maintenance with Cervical Spine Protection:

Evaluate the airway without delay. Depending on how the injury occurred, patients might need the following interventions:

- Opening the airway—this may be improved with a chin lift or jaw thrust maneuver.
- Placement of a nasopharyngeal or oropharyngeal airway (only for unconscious patients).
- Secure the airway through endotracheal intubation.
- Protect the cervical spine using in-line immobilization for patients with related trauma mechanisms (e.g., falls, motor vehicle accidents), high-voltage electrical injuries, and those with altered mental status.
- Facial burns can cause swelling, which may necessitate an urgent need for securing the airway; thus, it is essential to continually reassess the patient's airway.

B. Breathing and Ventilation

Ventilation, which involves the movement of air, depends on the proper function of the lungs, chest wall, and diaphragm. Assess this by:

- Listening to lung sounds and confirming equal breath sounds on both sides.
- Providing supplemental oxygen—evaluate the rate and depth of breathing.
- Initiate high-flow 100% oxygen via a non-rebreather mask if an inhalation injury is suspected (due to an indoor fire).
- Circumferential full-thickness burns on the chest and neck could restrict ventilation and should be monitored closely. It is essential to recognize that respiratory distress might be caused by a non-burn-related condition, such as a pre-existing medical issue or a pneumothorax resulting from an associated injury.

C. Circulation and perfusion

After burns, there is often an increase in circulating catecholamines, which can raise the heart rate in adults to between 100 and 120 beats per minute. Heart rates exceeding 120 bpm may suggest hypovolemia caused by associated trauma, inadequate oxygenation, unrelieved pain, or anxiety. Irregular cardiac rhythms could stem from electrical injuries, pre-existing cardiac issues, or electrolyte disturbances. A heart rate below 100 bpm is viewed as relative bradycardia and may indicate extremely low cardiac output due to medications like beta-blockers or underlying cardiac problems that might require deeper investigation.

Management

For burns covering more than 20%, two large-bore IVs or indwelling venous catheters are recommended, particularly during transport. In pre-hospital and early hospital settings, prior to assessing the Total Body Surface Area (TBSA) affected, the initial fluid rates for patients with visibly significant burns (greater than 20%) are determined by the patient's age (ABA, 2023):

- ≤5 years old: 125 ml of Lactated Ringer's (LR) per hour
- 6–12 years old: 250 ml of LR per hour
- ≥13 years and older: 500 ml of LR per hour

The exact calculation of hourly fluid rates (referred to as "adjusted fluid rates") will be made during the secondary survey. Circulation in a limb with a circumferential or almost circumferential full-thickness burn may be hindered by the buildup of edema. Common signs of restricted circulation (such as pain, pallor, and paresthesia) may not be reliable indicators in a burned limb and can manifest later. Conversely, the lack of a radial pulse distal to a full-thickness circumferential burn on the arm indicates poor circulation. A Doppler examination may also be utilized to verify the circulation issue.

It's important to note that compromised circulation rarely occurs immediately following the injury; rather, these compression syndromes usually develop after resuscitation has begun and edema sets in. Continuous monitoring of circulation in extremities affected by circumferential full-thickness burns is necessary throughout the resuscitation process. Acute burns do not typically result in bleeding. If bleeding occurs, there is likely another injury—investigate and address the cause. External trauma can also lead to internal bleeding, which in turn can cause tachycardia and hypotension. Maintain a strong suspicion for possible non-burn injuries if the mechanism of injury indicates other trauma (e.g., falls or motor vehicle accidents).

D. Disability

Patients with burns are generally alert and aware initially. If they are not, consider the possibility of associated injuries, carbon monoxide exposure, substance use, hypoxia, or pre-existing health conditions. Start the assessment by evaluating the patient's responsiveness using the AVPU method while the Glasgow Coma Scale (GCS) serves as a more precise tool for measuring the depth and duration of coma, which should be used to track the patient's alertness over time.

E. Exposure and Environmental Control

For minor injuries (i.e., ≤5% TBSA), cool the burn for a brief period (3–5 minutes) using cool water. Avoid the use of ice or very cold water. Extended exposure to cold compresses poses the risk of causing hypothermia in the wound and the body. Wound hypothermia can constrict blood vessels in the damaged area, potentially worsening the injury. Systemic hypothermia (core temperature below 95 °F/35 °C) can exacerbate the severity of the burn by causing vasoconstriction, reducing enzymatic activity, impairing reflexes, disrupting clotting mechanisms and respiration, and could lead to cardiac issues and death. This is particularly crucial for pediatric patients, who have a limited capability to maintain their core body temperature.

It is vital to keep the patient's core body temperature stable. The individual should be wrapped in warm, dry sheets and blankets to avert hypothermia. Infusing warmed intravenous fluids (37–40 °C) can also aid in resuscitation. If the burn has been previously cooled, remove any damp dressings and substitute them with a clean, dry cover. Use blankets to help rewarm the patient. Exceptions include tar and asphalt burns, which need to be thoroughly cooled with a large volume of cool water. In cases of chemical burns, remove any dry chemicals from the patient and rinse extensively with running water. Immediate irrigation is crucial in managing chemical injuries.

Secondary Survey

The secondary survey begins only after the primary survey has been completed and initial fluids have been administered. This secondary survey consists of the following components:

- Gathering history (including circumstances of the injury and medical background)
- Determining the patient's accurate weight prior to the injury
- Performing a comprehensive head-to-toe assessment of the patient
- Assessing the percentage of total body surface area (TBSA) that has been burned
- Implementing adjusted fluid rates following TBSA assessment
- Collecting necessary lab tests and X-rays
- Inserting a Nasogastric Tube (NGT) for patients who are intubated
- Inserting a Foley catheter and monitoring fluid resuscitation for patients with over 20% TBSA burns
- Managing pain and anxiety
- Providing psychosocial support
- Addressing wound care

Pre-Burn Weight

Fluid rates are adjusted based on the patient's weight before the burn. If a significant volume of fluid has been administered prior to determining hourly fluid rates, try to ascertain the patient's weight before the injury from the patient or a family member, if possible.

Depth of Burn

Burn injuries can be categorized by degrees or classified as partial versus full-thickness injuries. The extent of tissue damage resulting from a burn relies heavily on four factors:

- The temperature of the harmful agent
- The length of time in contact with the burning material
- The thickness of the epidermis and dermis
- The blood supply to the affected area

Burn depth is divided into partial (where some layers of skin sustain damage) versus full-thickness (where all skin layers are impacted). An additional classification method includes first-, second-, and third-degree. Individuals with circulatory issues might experience deeper burns more readily. Young children and elderly individuals have thinner skin, making their burns potentially deeper and more serious than they initially seem. It may take 48 to 72 hours to definitively assess the depth of the injury.

Extent of Burn

The "Rule of Nines" is the most frequently utilized method to estimate second-degree burns and deeper. In adults, specific anatomical areas correspond to approximately 9%—or multiples thereof—of the Total Body Surface Area (TBSA). In infants or children, the "Rule" varies due to the larger surface area of the child's head in comparison to the smaller surface area of their lower extremities.

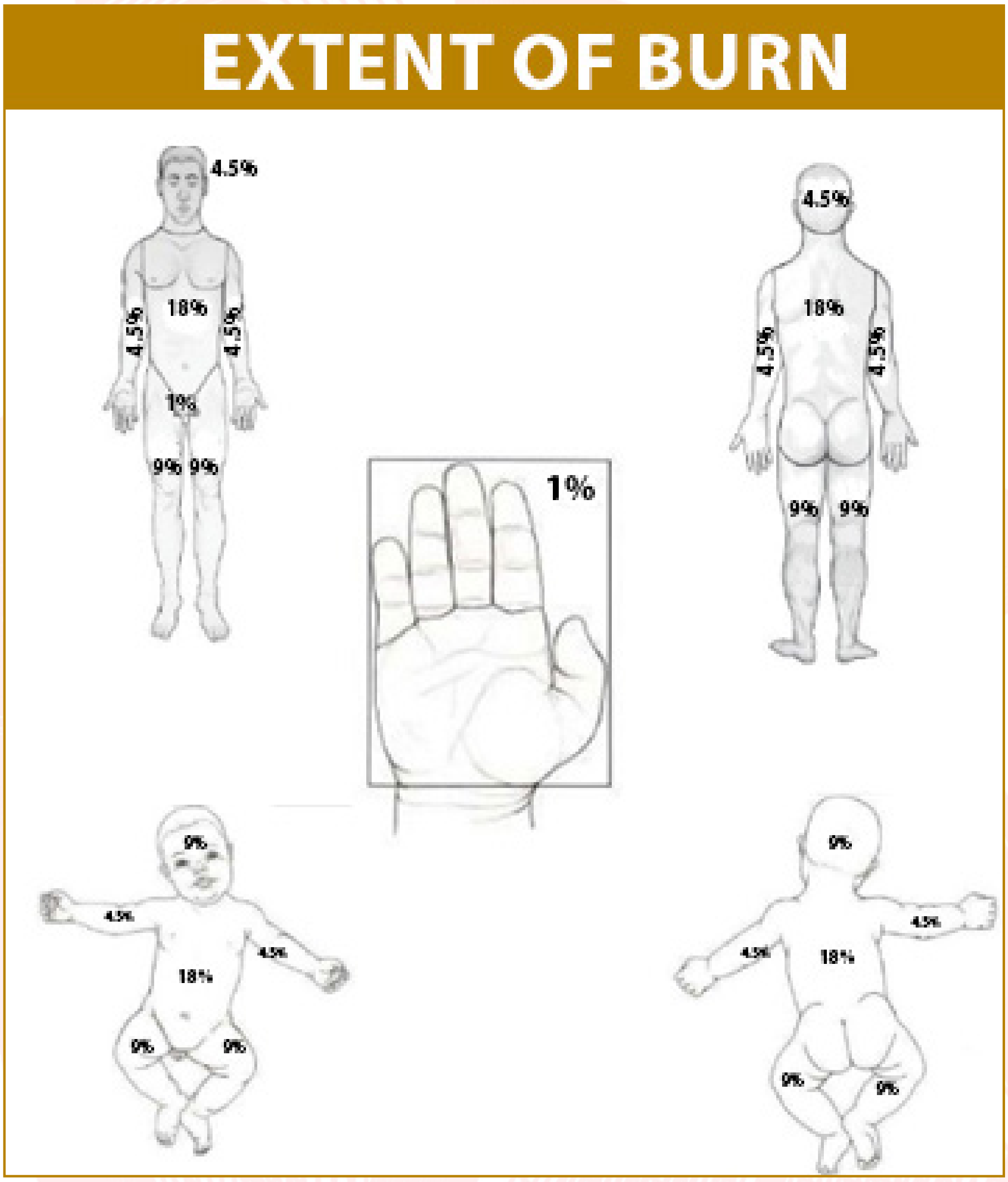


Figure 11.1 Rule of Nine

It is important to note that first-degree burns (superficial burns without blisters) are not factored into the total body surface area (TBSA) burn assessment and should not be considered for fluid resuscitation calculations. If only a portion of a specific anatomical region is burned, the TBSA percentage should be calculated based only on the extent of that area affected (for example, if the arm is burned all the way around from the wrist to the elbow, and only half of the arm is burned, this would represent about 4.5% of TBSA).

Burn treatment centers often use the Lund-Browder Chart for a more precise evaluation of the percentage of TBSA affected by the burn.

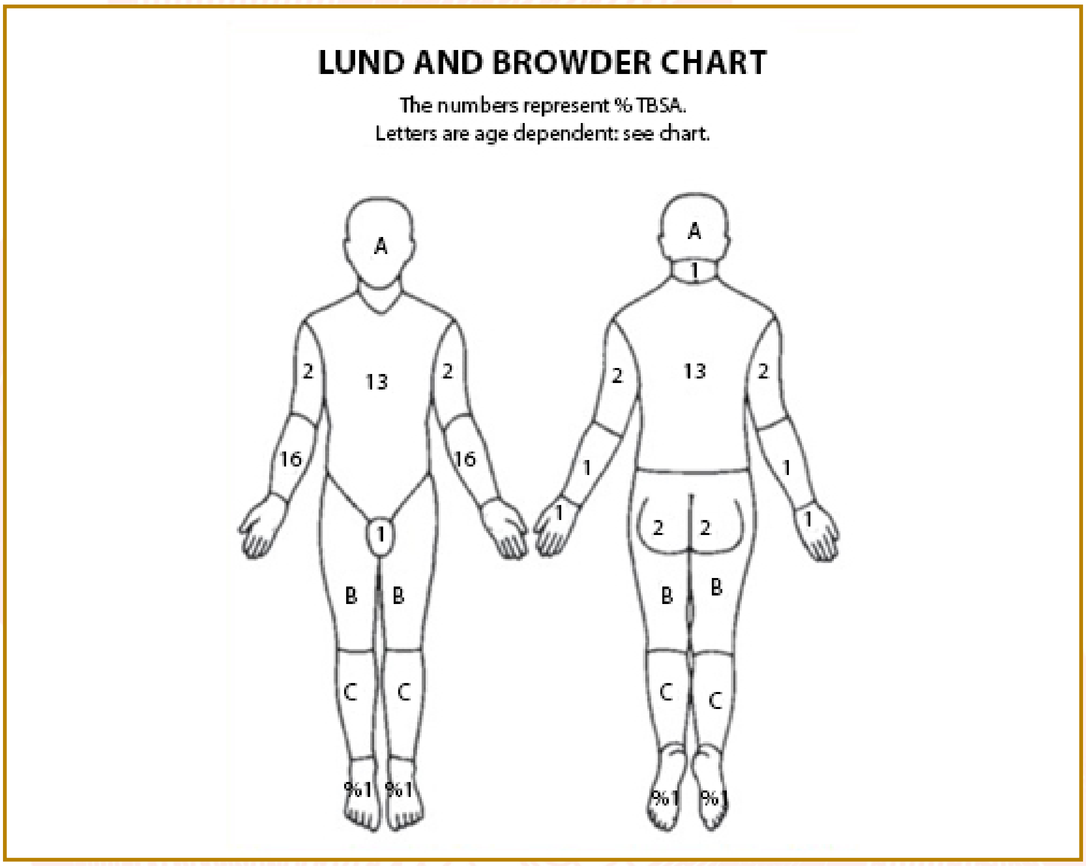


Figure 11.2 Lund-Browder Chart

Area	Age 0 yr	1 yr	5 yr	10 yr	15 yr	Adult
A = ½ head	9 ½	8 ½	6 ½	5 ½	4 ½	3 ½
B = ½ thigh	2 ¾	3 ¼	4	4	4	4 ¾
C = ½ leg	2 ½	2 ½	3	3 ½	3 ½	3 ¾

Estimating Size for Scattered Burns

The size of a person's hand—measured from the wrist crease to the fingertip of the longest finger, along with the palm's width—approximately equals one percent of their total body surface area. This technique provides a straightforward method for assessing the extent of unevenly distributed burns.

Management Principles and Adjuncts

Fluid Resuscitation

The modified fluid rates are determined based on the table provided below:

Category	Age and Weight	Adjusted Fluid Rate
lame or scald	Adults and teenagers (≥13 years old)	2 ml LR × kg × % TBSA = ml/24hrs ÷ 16 = ml/hr starting rate
	Children (≤12 years old)	3 ml LR × kg × % TBSA = ml/24hrs ÷ 16 = ml/hr starting rate Plus D_5LR at maintenance rate
Electrical Injury	All ages	4 ml LR × kg × % TBSA = ml/24hrs ÷ 16 = ml/hr starting rate Plus D_5LR at maintenance rate for children ≤12 years old

Table 11.1 Figure 11.2 Pediatric Lund-Browder Table

Some patients, such as those with a delayed initiation of fluid resuscitation, previous dehydration, substance use including alcohol, high-voltage electrical injuries, or inhalation injuries, may need more fluids than initially calculated. There is no specific calculation to factor in these conditions. Fluid rate modifications are again based on the patient's response, specifically urine output and blood pressure.

A useful indicator for assessing the effectiveness of fluid resuscitation is the patient's urine production (typically necessitating the use of a urinary catheter), which ought to be: 1ml/kg/h for adults and 2ml/kg/h for children.

2. Vital Signs

Vital signs should be monitored at least once an hour in patients with burns affecting 20% or more of total body surface area (TBSA).

3. Nasogastric Tube

A nasogastric tube should be inserted for patients who are intubated, and all patients should be monitored for any indications of nausea or vomiting.

4. Urinary Catheter

Utilizing a urinary catheter is essential since urine output is currently the most reliable indicator of sufficient organ perfusion and, consequently, fluid resuscitation. All individuals with burns ≥20% TBSA should have a urinary catheter. Additionally, a urinary catheter is advised for patients who are unable to urinate or when their overall fluid status is ambiguous, even in cases of smaller burns.

5. Monitoring Extremity Perfusion

In cases of constricting, circumferential burns of the extremities, the swelling that develops in the tissue beneath the burn eschar can gradually restrict blood flow. If this condition worsens to significantly diminish capillary and arterial flow, it could result in ischemia and necrosis. Elevating the affected limb can help reduce swelling. An escharotomy may be necessary to restore proper circulation; this procedure involves making a longitudinal incision through the burned skin (eschar) to allow for the expansion of the swollen subcutaneous tissue. Extremities that are initially deemed soft may start to feel increasingly tight as resuscitation progresses; hence, frequent reassessment is crucial.

6. Monitoring Ventilation

Circumferential burns to the chest and/or abdomen can limit ventilatory movement, and an escharotomy of the chest or abdomen may be required in both adults and children. Due to the more flexible rib cage in children, which makes it harder to counteract constriction from a circumferential chest burn, they may need an escharotomy sooner than adult patients.

7. Pain and Anxiety Management

Morphine (or comparable opioids) is recommended for managing pain. It is essential to differentiate between pain and anxiety. Benzodiazepines can also be utilized to reduce anxiety. Doses should be adjusted for effectiveness, using small, frequent intravenous administrations, as this approach provides more reliable absorption and effect than oral, subcutaneous, or intramuscular methods. It is not unusual for the opioid dosage needed to surpass conventional weight-based recommendations.

Continuous monitoring of respiratory function is crucial, as larger doses may be required to control pain and anxiety. On the other hand, high dosages could result in vasodilation, which increases the necessity for fluid resuscitation; hence, careful administration is critical. For burn patients, tetanus immunization is the sole recommended intramuscular medication. Elevate the patient's head and affected limbs, unless there are contraindications due to spine immobilization, raising the patient's head to 45 degrees. This will help to reduce facial and airway swelling and prevent aspiration. Additionally, raising burned limbs alleviates swelling.

INITIAL STUDIES

Skin burns can cause dysfunction of other organ systems. Thus, baseline screening tests are often performed

and can be helpful in evaluating the patient's subsequent course:

- Complete Blood Count (CBC)
- Serum chemistries/electrolytes (e.g., Na+, K+, Cl-)

- Blood urea nitrogen
- Glucose levels, especially in children and diabetics
- Urinalysis for pregnancy, toxicology, and in diabetics
- Chest X-Ray in intubated patients
- Toxicology screens, including blood alcohol level

Under specific circumstances, additional specialized tests are appropriate:

- Arterial blood gases with Carboxyhemoglobin level (Carbon Monoxide) if inhalation injury is suspected
- ECG – With all electrical burns or for patients with pre-existing cardiac disease
- Type and screen (or cross) for patients with associated trauma

Special Considerations.

A. Associated Trauma

Injuries ranging from minor to life-threatening can occur, depending on the nature of the incident (e.g., motor vehicle accidents, explosions, electrical injuries, crush injuries from building collapses, falls, or assaults). Associated trauma may hinder or impede escape from a fire scenario, potentially resulting in larger total body surface area (TBSA) burns or more serious inhalation injuries.

A delay in identifying associated injuries can lead to increased morbidity and mortality, along with extended hospital stays and higher care costs. Do not allow the visible condition of the burn to postpone a comprehensive trauma evaluation and the management of associated injuries.

B. The Pregnant Patient with Burns

Burn injuries in pregnant women are uncommon but can pose significant challenges for this vulnerable group. It is vital to assess and treat the mother as the primary patient through both primary and secondary surveys. Providing optimal care for the mother will result in the best care for the fetus. Favorable maternal and fetal survival outcomes are achievable in specialized facilities with obstetrical consultation.

C. Blast Injuries and Burns

Blast injuries encompass a broad range of trauma that may result from an explosion. Such injuries are increasingly recognized as a common mechanism of trauma in various regions of the world, with high-explosive incidents having the potential to cause mass casualties along with multi-system injuries, including burns. The severity of injuries is influenced by the quantity and type of explosive material, the blast environment, the distance from the explosion to the injured individuals, and the means of delivery.

Consideration must also be given to the use of radioactive substances and chemicals in unintentional injuries as well as in terrorism and warfare contexts. Blast injuries can be classified into four categories, either separately or in combination:

1. Primary: Resulting from the direct wave (pressurized air that re-expands) impacting the body. Injuries may include tympanic membrane rupture, lung damage, and injuries to hollow organs.
2. Secondary: Occur when debris propelled by the explosion causes penetrating or blunt trauma.
3. Tertiary: Result from victims being thrown by the blast wind. Injuries in this category include blunt or penetrating trauma, fractures, and traumatic amputations.
4. Quaternary: Encompass all other types of injuries, which may include flash burns, ignited clothing, crush injuries, inhalation injuries, asphyxiation, and toxic exposures.

The lung blast effect stands out as the most common fatal injury among those who survive the initial explosion. These types of injuries often present with a triad of apnea, bradycardia, and hypotension, along with symptoms such as difficulty breathing, coughing, coughing up blood, and chest discomfort.

A chest X-ray may reveal a butterfly pattern, a crucial sign of blast lung injury. The use of prophylactic chest tubes before transport is strongly advised. Symptoms of blast lung injury may appear immediately or may not develop for 24 to 48 hours following the explosion.

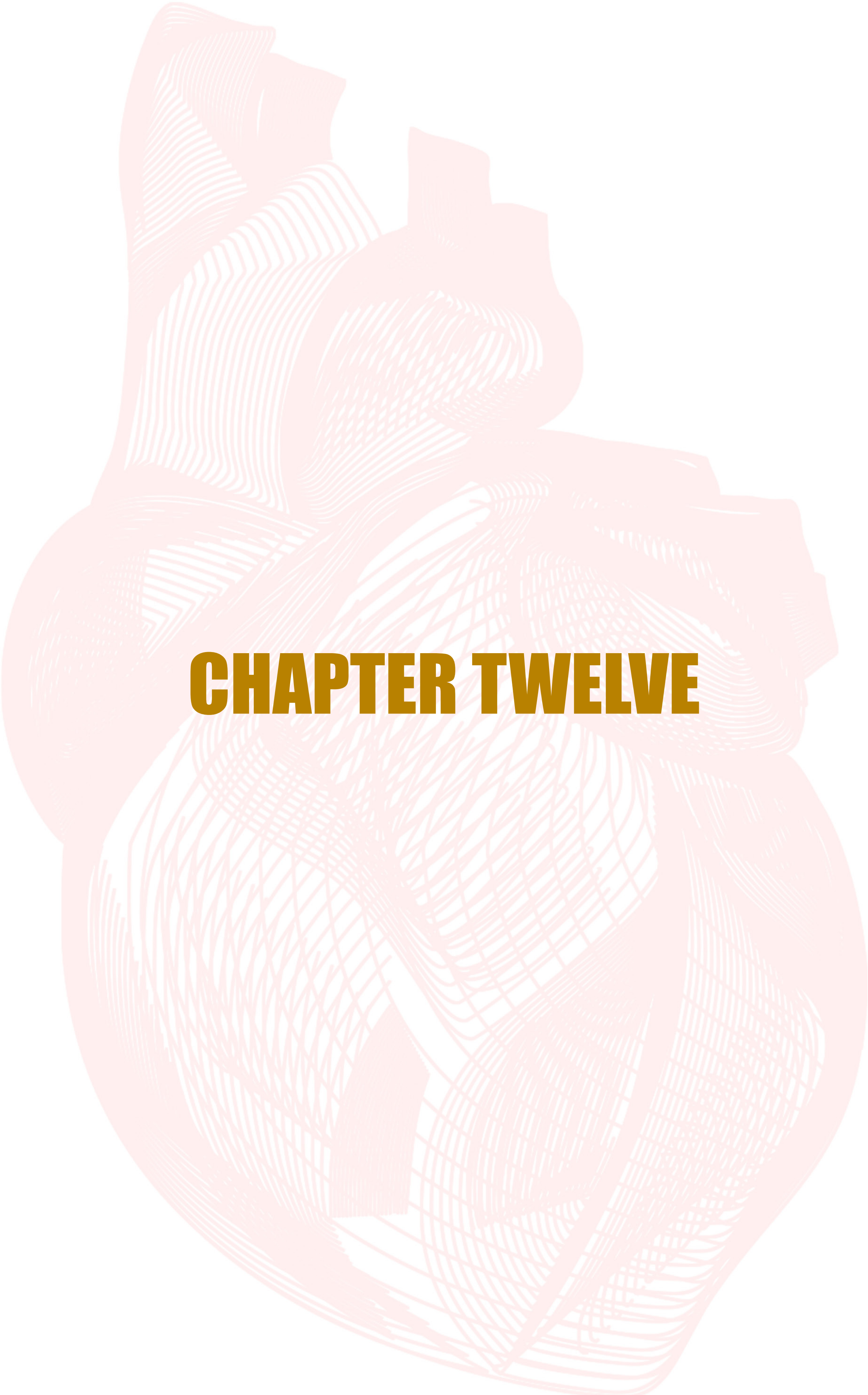
The tympanic membranes may burst due to overpressure, and supportive treatment is recommended for this condition. Intra-abdominal organs can sustain damage from the pressure wave and should be addressed as one would treat any blunt abdominal trauma. Consideration should be given to bowel ischemia and/or rupture. Additionally, brain injury is believed to be common in cases of primary blast injuries, and individuals suspected of such injuries should receive brain imaging.

Referral Criteria

The American Burn Association (ABA) has established guidelines to aid in the consultation and transfer of patients with burn injuries after the initial assessment and stabilization at a referring facility.

Category	Immediate Consultation with Consideration for Transfer	Consultation Recommended
Thermal Burns	- Full-thickness burns - Partial thickness ≥10% TBSA* - Any deep partial or full-thickness burns involving the face, hands, genitalia, feet, perineum, or over any joints - Patients with burns and other comorbidities - Patients with concomitant traumatic injuries - Circumferential injuries - Poorly controlled pain	- Partial thickness burns <10% TBSA* - All potentially deep burns of any size
Inhalation Injury	All patients with suspected inhalation injury	Patients with signs of potential inhalation, such as facial flash burns, singed facial hairs, or smoke exposure
Pediatrics (≤14 years, or <30 kg)	All pediatric burns may benefit from burn center referral due to pain, dressing change needs, rehabilitation, patient/caregiver needs, or non-accidental trauma	
Chemical Injuries	All chemical injuries	
Electrical Injuries	- All high-voltage (≥1000V) electrical injuries - Lightning injury	Low-voltage electrical injuries (<1000 V) should receive consultation and consideration to follow-up in a burn center to screen for delayed symptom onset and vision problems

Table 11.3 The American Burn Association (ABA) guidelines for consultation and transfer of patients with burn injuries



CHAPTER TWELVE

Pediatric Trauma

Learning Objectives:

At the end of this chapter, the reader will be able to:

- Know the differences between adult and pediatric trauma victims.
- Approach the pediatric victims with trauma following primary and secondary approach.
- Recognize the most common trauma among pediatrics.
- Describe basic management of common injuries seen in pediatric patients

Introduction

Trauma remains the primary cause of illness and death among children. In many high-income nations, injuries impose the greatest impact in terms of health complications and fatalities for pediatric populations. In the United States, the mortality rate for children resulting from injuries rose by 12% from 2013 to 2016, and a report from 2016 indicated that over 7% of children experience a significant head injury before reaching 17 years. In Canada, approximately 900 children and teens die, and 35,000 are admitted to hospitals each year due to injuries.

Globally, the leading causes of death in children include motor vehicle accidents, drowning, falls, burns, and poisoning. Saudi Arabia reports the highest rate of road traffic accidents worldwide, with an accident-to-injury ratio of 8:6, compared to an international average of 8:1.8. Furthermore, a significant portion of Saudi Arabia's population—40%—is aged 19 or younger, highlighting the serious implications of childhood injuries on the nation's health.

Research conducted in Makkah, Saudi Arabia, found that trauma predominantly affects children aged one to five years (41.5%). In both girls and boys, the most frequent cause of injury was falling from a height (41.8%). The majority of injuries were to the extremities (59%), followed by the head (34.7%).

Anatomically, physiologically, cognitively, and psychologically, children differ from adults. This chapter intends to explore these differences and their effects on the evaluation and treatment of traumatic injuries in children. The discussions will focus on how these variances influence:

- Mechanism of injury
- Pattern of injury
- History
- Examination and management

Initial Trauma Evaluation

Numerous anatomical and physiological distinctions influence the impressions gathered from the assessment and objective data and may alter the decisions made regarding care. In general, the normal ranges for vital signs shift as a child develops, so it is crucial to evaluate vital signs and examination results within the framework of age.

Additionally, children exhibit enhanced hemodynamic compensation, making hypotension a very late indication of shock. Both weight and size are critical for determining medication dosages and the appropriate size of equipment used.

Resources and tools like the Broselow tape are available to assist in estimating weight and dosing essential medications accurately. Communication can be challenging, even with children who can express themselves verbally. Having a parent present at the bedside, particularly if there are staff members ready to explain the situation to the parent, can be beneficial for both the parent and the child. The fundamental approach to the trauma examination remains consistent—ABCDE—but each component of the assessment will necessitate slight modifications from adult protocols.

Airway

Infants and young children possess an anterior, narrower, and shorter airway, which can create challenges in managing the airway. Additionally, the pediatric airway is prone to easy blockage, whether by foreign objects or by the tongue obstructing it. Because children can quickly become hypoxemic and oxygen deprivation can have severe hemodynamic consequences, it is crucial to understand effective airway management methods, including intubation and simpler supportive techniques. Preoxygenation is even more critical for younger children for these reasons.

If airway evaluation suggests a need for action, take into account the positioning and the use of adjuncts. In younger children, the head tends to be proportionally larger, and using a shoulder roll can help to better align the airway. For older children and adolescents, particularly those with obesity, standard positioning and ramping are generally more suitable. The trachea is softer and more compressible in younger individuals, so laryngeal manipulation should be conducted cautiously to avoid causing an iatrogenic airway obstruction.

Using an airway adjunct—such as a nasopharyngeal airway for those with a gag reflex or an oropharyngeal airway for those without—can promote effective oxygenation and ventilation prior to the insertion of a more advanced airway. It's advisable to consult a bedside reference for the correct sizing of equipment.

Recent studies indicate that using cuffed endotracheal tubes is safe and leads to better outcomes even in neonates. While video assistive technology is available for pediatric patients, it's not accessible in many facilities and should not be overly depended upon. The first-attempt success rate for intubation is lower in children compared to adults, and around one-third of pediatric patients experience desaturation events during intubation; therefore, it's important to prepare for success from the outset.

Although rare, airway obstruction is a serious issue that can result in high mortality rates. The pediatric airway is smaller, and the tracheal rings are less calcified than those in adults. Thus, performing a traditional cricothyroidotomy on younger children is often impractical.

Traditionally, it has been suggested that a cricothyroidotomy can be performed between the ages of 10 and 12, but this should also take the child's size into consideration. For smaller children, the procedure may not be appropriate. A needle cricothyroidotomy serves as an alternative temporary method for oxygenation (rather than ventilation) until a surgical tracheostomy can be executed or the obstruction is resolved. When total airway blockage occurs, the respiratory rate used during needle cricothyroidotomy should be lower than typical to reduce the chance of barotrauma.

Breathing

The respiratory rate decreases as a person matures, with normal rates in infants reaching up to 60 breaths per minute. When ventilatory support is necessary, it is crucial to mimic physiological rates and volumes.

There are different ventilator configurations, such as high-frequency oscillatory ventilation, designed for infants and young children who are challenging to ventilate. Nevertheless, using these alternatives in acute trauma situations is unlikely to be suitable and should preferably be handled by pediatric critical care specialists.

Circulation

Evaluating hemodynamics in pediatric patients is complex due to their significant compensatory mechanisms. Blood pressure can remain stable after trauma even with a blood loss of up to 30%, making hypotension a late indicator of shock.

Tachycardia may occur before hypotension, but its development can also take some time. Capillary refill can serve as an indicator of approaching shock, although it may be inaccurate due to variations in temperature and personal responses to hypovolemia.

Children are especially vulnerable to hypothermia, and even warmed blood flowing at reduced rates can lose heat within intravenous (IV) lines. While warming devices and insulated IV tubing for pediatric blood transfusions are available, they might not be accessible in every facility. If warming blood isn't feasible in a given situation, it is crucial to monitor for hypothermia and employ alternative warming methods to help sustain normothermia.

Massive transfusions occur infrequently but come with significant morbidity and mortality risks. The existing evidence for determining the timing of transfusions and deciding between crystalloids and blood products is limited, leading to ongoing debates.

Some pediatric guidelines still recommend isotonic fluid resuscitation up to 60 mL/kg (administered in 20 mL/kg increments) before starting blood transfusions; however, more recent studies indicate that earlier blood administration might be advantageous. Blood products should be given in increments of 10 mL/kg. The term "massive transfusion" is not uniformly defined across the literature, ranging from the transfusion of 50% of blood volume (approximately 40 mL/kg) to 100% of blood volume within 24 hours.

The optimal ratios for blood products have not yet been conclusively established for children, though recent research suggests a preference for a 1:1 ratio of packed red blood cells to fresh frozen plasma (FFP). Coagulopathy is particularly concerning in neonates, as their hemostatic system does not fully mature until around 6 months of age.

Establishing IV access can be challenging in younger children or those with low blood volume. Intraosseous (IO) access is typically the preferred approach for initial resuscitation when IV access cannot be successfully achieved (after 2–3 attempts or within 90 seconds) or is inadequate for resuscitation efforts. Suitable sites for IO access in a young child include the distal femur as well as both the proximal and distal tibia. The humeral head may be utilized once the greater tuberosity can be felt, usually around 6 years of age. While central venous access is an option, it can be technically complicated in younger patients, requires appropriately sized tools, and carries a higher risk of complications. Surgical cut down should be considered only as a last option. Code medications may be administered endotracheally for a patient in cardiac arrest; however, this method is less than ideal due to unpredictable absorption and does not facilitate volume resuscitation.

Disability

The Glasgow Coma Scale (GCS) has a recognized pediatric version that features verbal sub-scores categorized by specific age groups, allowing for comparison to age-appropriate norms. The pediatric GCS also includes slight modifications to the scoring for motor responses and eye-opening, facilitating assessments for children too young to follow commands.

A GCS score of 8 or less raises concerns about severe brain injury and may require intubation similar to adults, although it is crucial to evaluate the individual clinical situation and perform controlled intubation when feasible. Conducting a neurologic examination can be more difficult in younger patients; however, various movements and reactions might be elicited by capturing the child's attention in different directions, with help from a parent if present.

Cervical spine stabilization can be difficult in children of all ages, as it involves not only finding a properly sized cervical collar but also convincing a child to keep it on. Proper sizing is crucial because a collar that doesn't fit correctly can lead to excessive flexion or extension, and pediatric cervical spine injuries tend to occur more frequently in areas where motion is possible. If an appropriately sized cervical collar is not available or if standard collars do not fit a child well (which may happen in cases of dysmorphia), rolled towels can be used and secured with tape for stabilization. Most spinal injuries in children happen in the cervical region, making proper immobilization essential.

The routine application of backboards is not advisable. Research indicates that there is no improvement in spinal cord injury rates with their regular use. Concerns include delays in receiving definitive care, increased risk of pressure injuries, pain caused by the backboard, and possible respiratory issues. Although backboards might be necessary for safe extrication in emergency situations, it is important to remove patients from them as soon as possible.

Patients should be logrolled when placed onto or taken off the backboard, at which point assessing for spinal injury risk is appropriate to determine if logrolling should continue. It is typical and acceptable for Emergency Medical Services (EMS) to transport a stable child with no evident neurological issues in their car seat, provided the car seat shows no visible signs of damage.

When taking a child out of the car seat, it is important to use manual in-line stabilization, even if the child is wearing a cervical collar. After the child is unbuckled and held in stabilization, the back of the car seat should be positioned parallel to the ground, allowing the child to slide out from the upper part of the car seat onto the stretcher, thereby maintaining spinal alignment.

Workup and initial management of the critical trauma patient

The ABCDE algorithm should be emphasized as noted. An important initial step includes estimating the weight and size of the child. Most medications are dosed based on weight, and the equipment used varies according to the child's size and weight. The Broselow tape is the most commonly used tool for estimating weight in pediatric patients, and it is often found in pediatric code carts, making it familiar to many physicians.

Laboratory work for pediatric patients with evident multisystem injuries will be similar to that for adults. Tests should include a complete blood count, comprehensive metabolic panel, lipase, type and screen, coagulation factors, and urinalysis. Lactate and base deficit have been evaluated for their relevance in the pediatric population, with some evidence supporting that base deficit may help predict the need for blood transfusions. Although the evidence is not strong enough to recommend obtaining a Venous Blood Gas (VBG) for base deficit as standard practice, it can be reasonable to acquire it as an additional tool for understanding the complete clinical picture.

Multiple studies have linked elevated lactate levels, with thresholds ranging from 2.9 to 5.1 mmol/L, to an increased risk of mortality; however, its specific application in clinical practice and subsequent management changes remain unclear. Nonetheless, obtaining this value is sensible. Troponin levels and Electrocardiograms (EKG) are indicated if there is a suspicion of blunt cardiac injury. Toxicology screenings and pregnancy tests should be performed as warranted by the clinical context.

Imaging techniques in critical trauma are similar for both pediatric and adult patients. The use of computerized tomography (CT) scans should be approached cautiously due to radiation risks, but they can still be justified in cases of significant multisystem trauma, supplemented by x-rays when clinically necessary. For patients who are hemodynamically unstable and not stable enough for CT, consideration should be given to the Operating Room (OR).

Focused Assessment with Sonography for Trauma Evaluation (FAST) is utilized less frequently in pediatric trauma compared to adult cases, but studies have been conducted. The negative predictive value of FAST is lower in pediatric patients, with studies showing that 26% to 35% of those with hemoperitoneum detected via CT are missed by FAST. However, a positive FAST result in an unstable pediatric trauma patient provides valuable evidence for the need for a chest x-ray, a useful screening method before proceeding to chest CT, even in critically ill children; a normal chest x-ray is often a reliable test for ruling out thoracic injuries requiring intervention.

Chest CT should be reserved for patients exhibiting physical exam findings indicative of major thoracic trauma, abnormal x-ray results, or suspected tracheo-bronchial injury. For hemodynamically unstable patients suspected of having a pelvic fracture, pelvic x-rays are warranted, although their sensitivity for detecting pelvic fractures in pediatric patients is as low as 50%, making them an inadequate sole basis for ruling out such fractures.

Pediatric Penetrating Trauma

Penetrating injuries are less common in children than in adults.

Head Injuries

Pediatric penetrating head injuries are uncommon and have a mortality rate of up to 40%. When evaluating a pediatric patient, the assessment should incorporate a Glasgow Coma Scale (GCS) and a neurologic examination appropriate for the child's age. The causes of head injuries also vary in children.

While adolescents may be more susceptible to pediatric gunshot wounds (GSW) or self-inflicted head trauma, younger children are more likely to experience accidental injuries. In cases of accidental injuries, objects commonly penetrate the thinner roof of the orbit or the squamous part of the temporal bone.

Children are also at a greater risk of developing infectious complications from penetrating head injuries compared to adults, with up to 50% of pediatric patients experiencing infections. Factors that increase the risk of infections include cerebrospinal fluid (CSF) leaks, involvement of the sinuses, and the materials involved in the injury, such as graphite or wood.

Antibiotics should be routinely given in the emergency department (ED) to cover Staphylococcus, gram-negative bacteria, and Clostridium. For the prevention of seizures in younger children, current practices indicate the initial use of anticonvulsant medications and then consulting with the neurosurgery team about long-term anticonvulsant therapy.

Thoracic injuries

With penetrating Thoracic trauma, there should be a high suspicion for multiple injuries and potential decompensation. In pediatric penetrating thoracic trauma, mortality is inversely proportional to patient age, and death occurs in up to 14% of cases.

Hemothorax and concomitant injury are independently associated with mortality. Compared with the adult population, pediatric patients have a lower risk of rib or sternum fractures, flail chest, and hemothorax.

Pediatric patients with penetrating thoracic trauma have also been shown to need a greater amount of blood products per kilogram compared with their adult counterparts. Up to 35% of these patients will require operative intervention, and approximately one-third of these injuries will be able to be managed with tube thoracotomy alone.

Abdominal injuries

The small bowel is more frequently injured in penetrating abdominal injuries than the large bowel, which is more frequently injured than the liver. shock, the amount of organ damage, the required blood transfusion rate, and concurrent thoracic trauma all indicate a higher chance of complications from occurring.

Although minimally invasive laparoscopic surgery or observation can be used in hemodynamically stable pediatric patients with penetrating abdominal trauma, exploratory laparotomy has historically been the gold standard for managing these patients. This strategy could lower the risk of morbidity and death from exploratory laparotomies.

Pediatric Blunt Trauma

Head Injuries

Head injuries are particularly common, especially in young children and infants because of their weak cervical muscles and proportionately large heads. The commonly used Pediatric Emergency Care Applied Research Network (PECARN) criteria was implemented to reduce the number of unnecessary CT scans performed on children. While the effectiveness of this goal has varied across the country, it has been shown that its use can lower CT scan rates; therefore, PECARN criteria should be taken into consideration when choosing brain imaging for a stable child with a GCS of 14 or higher.

PECARN - Pediatric Head CT Rule	PECARN - Pediatric Head CT Rule
Younger than 2 years	**2 years or older**
CT Head Recommended if: AMS (Altered Mental Status) GCS < 15 Palpable skull fracture	**CT Head Recommended if:** AMS GCS < 15 Signs of basilar skull fracture
Observation vs. CT Head if: LOC > 5 sec Non-frontal hematoma Not acting normally Severe mechanism	**Observation vs. CT Head if:** History of LOC History of vomiting Severe headache Severe mechanism
No CT Required! (Discharge)	**No CT Required! (Discharge)**

Figure 12.1 Pediatric Emergency Care Applied Research Network (PECARN) criteria

Imaging is recommended for patients with a GCS of less than 14 or who may have a basilar skull fracture. While CT has traditionally been the preferred imaging modality, fast MRI protocols are becoming more widely available, and they offer a viable radiation-free alternative for stable patients.

MRIs can also be used to track how injuries are healing. Both adults and children can experience similar injury patterns, such as cerebral contusions, diffuse axonal injury, and intraparenchymal, subdural, and subarachnoid hemorrhages.

Children's epidural hematomas typically have a different etiology, with the most common cause being bleeding from the margins of fracture sites, which is frequently venous in nature. When it comes to children, subdural hematomas may cause more severe damage to different structures than epidural hematomas.

Neurosurgical consultation should be obtained in conjunction with the management of intracranial bleeding. Hyperosmolar therapy with either mannitol or hypertonic saline is appropriate if herniation is a cause for concern. The evidence supporting the use of hypertonic saline is more robust, while the evidence for mannitol, although less high-quality, is still commonly used.

The Guidelines for the Management of Pediatric Severe Brain Injury recommend an initial bolus dose of 3% hypertonic saline at 2 to 5 mL/kg, given over 10 to 20 minutes, which is a level II recommendation.

Skull fractures are not uncommon, and they can be seen either in conjunction with intracranial hemorrhage or as an isolated injury. Simple linear skull fractures often require only supportive care, but depressed or comminuted fractures require neurosurgical input and potential intervention.

Topics	Recommendations
Hyperosmolar therapy	Level I|I For ICP control II.1. Bolus hypertonic saline (3%) is recommended in patients with intracranial hypertension. Recommended effective doses for acute use range between 2 and 5 mL/kg over 10-20 min. Level III For ICP control III.1. Continuous infusion hypertonic saline is suggested in patients with intracranial hypertension. Suggested effective doses as a continuous infusion of 3% saline range from between 0.1 and 1.0 mL/kg of body weight per hour, administered on a sliding scale. The minimum dose needed to maintain intracranial pressure ICP < 20 mm Hg is suggested. III.2. Bolus of 23.4% hypertonic saline is suggested for refractory ICP. The suggested dose is 0.5 mL/kg with a maximum of 30 mL. Safety recommendation (applies to all recommendations for this topic). In the context of multiple ICP related therapies, avoiding sustained (>72 h) serum sodium > 170 mEa/L is suggested to avoid complications of thrombocytopenia and anemia, whereas avoiding a sustained serum sodium >160 mEq/L is suggested to avoid the complication of deep vein thrombosis. Note. Although mannitol is commonly used in the management of raised ICP in pediatric traumatic brain injury, no studies meetina inclusion criteria were identified for use as evidence for this tonic.

Table 12.1 Brain Trauma treatment

Concussions are also prevalent among children and adolescents. The symptoms can vary from mild and short-lived to severe and prolonged, taking months to fully resolve. Pediatric patients tend to have a longer recovery period compared to adults.

Thoracic Trauma

Pediatric thoracic trauma is relatively uncommon, but it is accompanied by a disproportionately high rate of morbidity and mortality. The rib cage in children is more flexible due to the non-ossification of the costal cartilage, which allows greater forces to be transmitted to the underlying organs but decreases the likelihood of rib fractures. The mediastinal structures also have increased mobility, leading more often to tension physiology.

Common injuries include pulmonary contusions, pneumothorax, and hemothorax. While mediastinal injuries are rare, they can result in mortality rates up to 32% within the first hour. Chest x-ray is the most appropriate initial screening tool for thoracic injuries, and the diagnosis and treatment of these injuries is generally similar to that of adult patients.

In pediatric patients, the abdominal organs are proportionally larger and less protected by the rib cage due to the flexibility mentioned above. The workup should begin with a physical examination, as generalized abdominal pain and tenderness are sensitive markers for intra-abdominal injury in a neurologically intact patient. Abdominal distension and bruising, including seatbelt signs, are also concerning indicators.

Laboratory tests can be used as a screening tool for intra-abdominal injury in hemodynamically stable patients. Elevated transaminases, with an AST above 200 U/L or ALT above 125 U/L in blunt abdominal trauma, or an elevation above 80 U/L of either in the setting of non-accidental trauma (NAT), should prompt further imaging with CT. If microscopic hematuria is present, renal imaging should be considered.

Handlebar injuries, in particular, can cause delayed presentation and commonly involve pancreatic and hollow viscus injuries, which are frequently missed or misdiagnosed, so a high index of suspicion is warranted. Solid organ injuries (spleen, liver, and kidney) are common and often can be managed non-operatively, with failure rates of non-operative management less than 5% for hemodynamically stable patients.

While CT has traditionally been the imaging modality of choice for evaluating intra-abdominal injuries, concerns about ionizing radiation have led to the exploration of alternative evaluation tools, such as contrast-enhanced ultrasound (CEUS), which has shown promise.

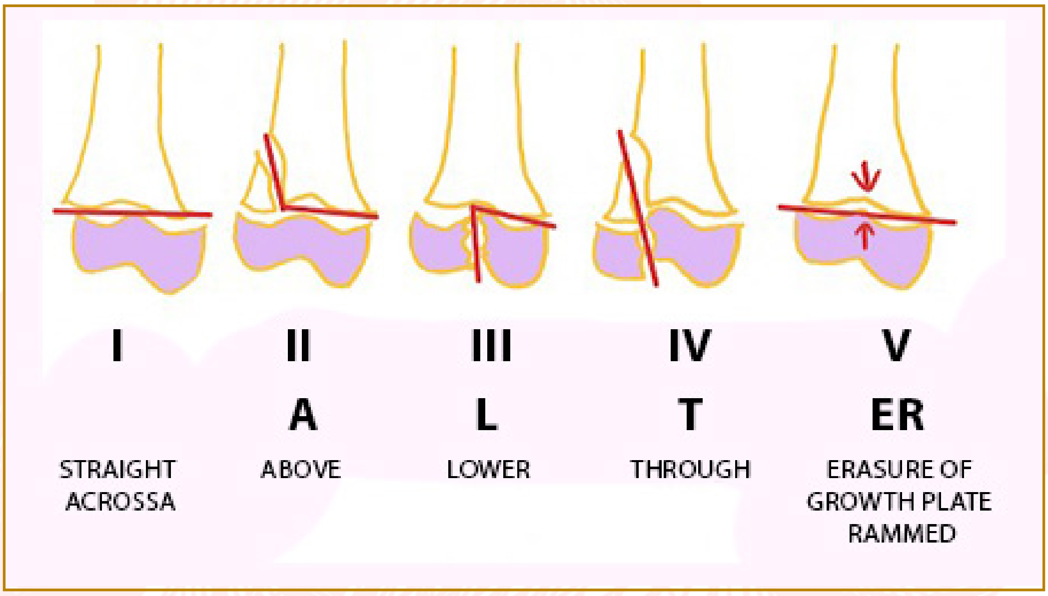


Figure 12.2 The Salter–Harris classification system

Extremity Trauma

Trauma affecting the extremities is incredibly prevalent in pediatric patients, and there are a few crucial factors to keep in mind. The Salter–Harris classification system is utilized for fractures that involve the growth plate, which can account for up to 20% of all pediatric fractures. Salter–Harris Type I fractures solely affect the physis and may not be easily visible on x-ray imaging due to this characteristic.

If there is a clinical suspicion based on the patient's history and bony point tenderness is present on physical examination, these individuals should be immobilized. Other significant fractures to be aware of include those in a non-mobile infant, injuries that do not align with the reported description of events or lack a clear explanation, and multiple injuries occurring at an early age. Certain fracture patterns, such as classical metaphyseal lesions (corner or bucket handle fractures), are more commonly associated with non-accidental trauma (NAT); however, many fractures are non-specific in nature.

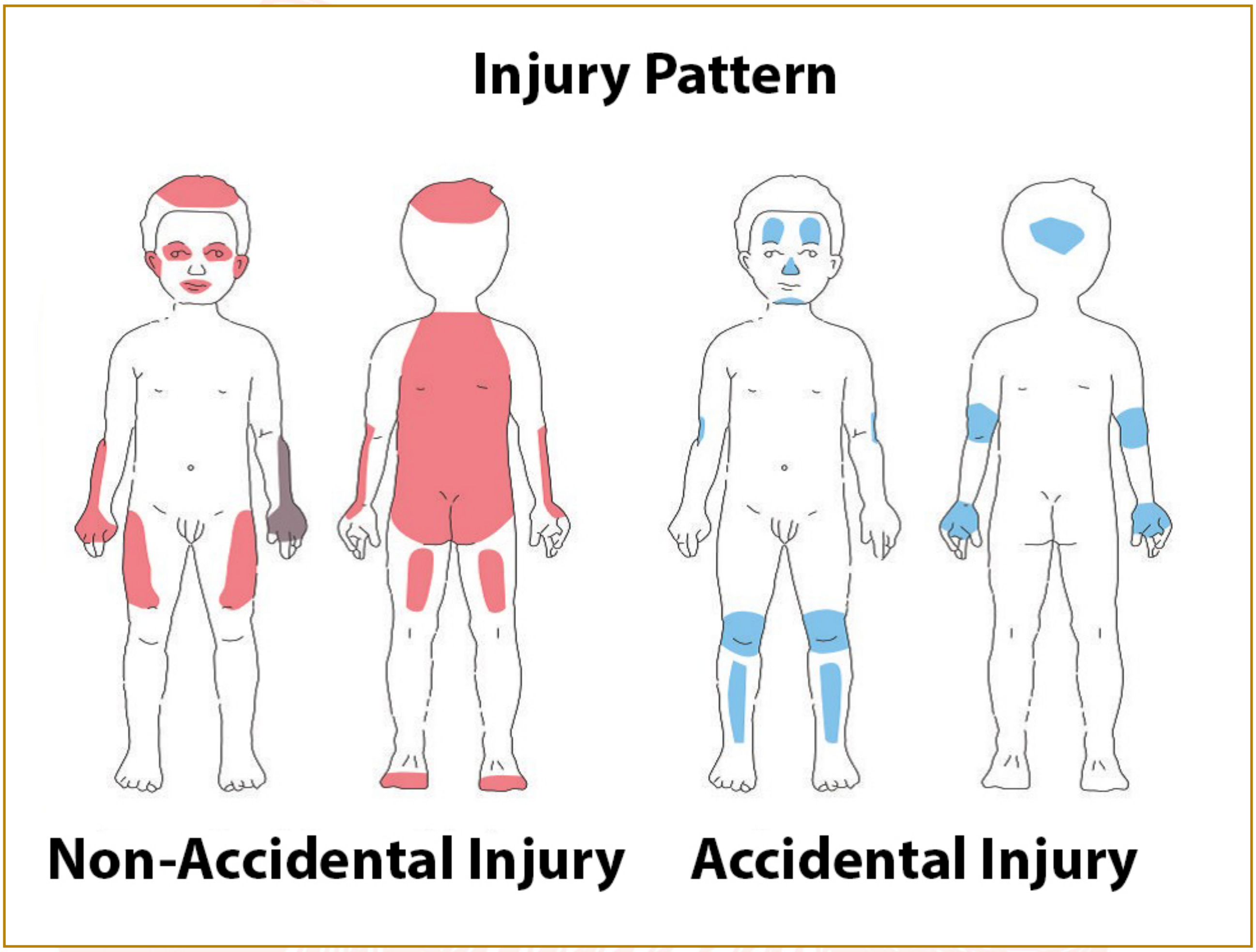


Figure 12.3 Non-accidental trauma (NAT)

Emergency medicine specialists should be attentive to the context of all injuries. While peripheral vascular injury is infrequent, it can occur in pediatric patients, and management approaches vary. Computed tomography is often utilized, although Doppler ultrasound may also be a viable diagnostic tool.

A substantial portion of cases necessitates surgical intervention, followed by anticoagulant or antiplatelet treatment. However, there is a paucity of dedicated pediatric literature to guide best practices for either management or optimal imaging in this context.

CHAPTER THIRTEEN

Inter and intra-hospital transfer of the trauma patient

Learning Objectives:

At the end of this chapter, the reader will be able to :

- Understand how to manage complex transfer situations
- Comprehend the importance of the trauma system and high performance team in management of trauma victims..
- Understand the roles and responsibilities of Trauma Team Leader (TTL) and team members.
- Make difficult decisions during transfers based on transfer principles.

Introduction

Patient transfer, whether to a different facility or within the same hospital, is a critical yet often overlooked aspect of healthcare. The decision to transfer is weighed between the care advantages at another facility and the associated risks. When considering a patient transfer, the potential improvement in management or outcomes from additional care must be evaluated. The risks involved in moving a critically ill patient are significant.

Factors necessitating patient transfer include limited availability of super-specialty centers, specialty bed shortages, and medical treatment funding. Transfers, whether within or between hospitals, should prioritize the patient's health, aiming for the closest facility that offers the most advanced specialized care.

Continuity of care is essential, and both sending and receiving facilities must ensure this. Disorganized and rushed patient transfers can greatly increase the risk of morbidity and mortality.

Trauma systems

Trauma systems integrate the collaboration of prehospital services, hospitals, and rehabilitation facilities within a specific geographic area, all coordinated with a regional public health system. This definition by Hofman and Pepe encapsulates the objective of trauma care systems: to deliver optimal care to patients with traumatic injuries, tailored to the severity of their injuries, and to do so as swiftly as possible. This care is provided by designated trauma centers that offer varying levels of service.

The concept of trauma care and systems has its roots in military emergency services, where the systematic management of severely injured patients was first developed. From the 'flying ambulances' of the Napoleonic wars in the 19th century to the Vietnam War in the 1960s and 1970s, significant insights were gained on how to triage, treat, and transport soldiers from the battlefield, leading to higher survival rates.

There are two distinct models of trauma systems. The "exclusive" model centers around a Level-1 trauma center, which provides immediate care for the most critically injured patients. On the other hand, the "inclusive" model is designed to cater to all injured patients within a specific region, incorporating all levels of care regardless of the severity of the injuries. This approach ensures that patients are treated at the appropriate level of care and that minor injuries are not escalated to major trauma centers, thus optimizing the use of healthcare resources. Ideally, every hospital with an emergency department should be equipped to treat injured patients according to their resources, expertise, and role within the community.

In this system, Trauma Units are equipped to assess and stabilize patients with injuries, yet they have limited resources for continued care, especially for those with head injuries or multiple injuries that require intensive care. Major Trauma Centers, on the other hand, are fully equipped to handle seriously injured patients at all times.

Trauma Triage Tool

1. VITAL SIGNS

- Sustained respiratory rate <10 or >29
- Sustained Systolic Blood Pressure <90 mmHg
- GCS MOTOR Score 4 or less
- (Consult JRCALC for expected age-specific paediatric thresholds)

Yes to any of these → **MTC** Discuss with Trauma Desk

NO →

2. ANATOMY OF INJURY

- Significant chest injury and hypoxia
- Major pelvic fracture
- Penetrating injury to head, neck, torso, armpit, gluteal region, or groin
- Open or depressed skull fracture
- Spinal injury with paralysis
- 2 or more humerus or femur fractures
- Open fracture, amputation, or mangled extremity proximal to forefoot or wrist

Yes to any of these → **MTC** Discuss with Trauma Desk

NO →

3. OTHER CONDITIONS

- Clinician judgement of significant injury
- Significant burns/scalds, circumferential or facial
- Anticoagulants, a death on scene, pregnancy, morbid obesity
- Patients >65 years – Consider Silver Trauma Safety Net

Yes to any of these → **Discuss with Trauma Desk** for Destination Advice

Algorithm 13.1 Trauma Triage Tool

Pre-hospital triage relies on a predefined tool to ensure trauma patients are directed to the most suitable care level; the right patient is taken to the right facility on the first attempt. Patients with serious injuries should be taken directly from the scene to the Major Trauma Center, bypassing local hospitals and trauma units. However, there are circumstances, such as the time of day, weather conditions, and distance to the nearest Major Trauma Center, where patients must be transported to the closest Trauma Unit for initial stabilization, imaging, and possibly surgery to manage ongoing bleeding, followed by transfer to a Major Trauma Center for comprehensive care.

A.T.M.I.S.T. Handover Tool		
AGE	Age and sex of casualty (demographic).	(5 Seconds)
TIME	Estimated time of arrival and the time of incident.	(10 Seconds)
M.O.I.	Mechanism of injury. This should include: - The gross mechanism of injury (e.g. motor vehicle crash or stab wound to the chest) and, - Details of other factors known to be associated with major injuries e.g. entrapment, vehicle rollover, occupant ejected from vehicle.	(20 Seconds)
Injuries	Seen or suspected.	(25 Seconds)
Signs	- Vital signs including heart rate, blood pressure, respiratory rate, oxygen saturation and Glasgow Coma Score. - An indication as to whether the physiological state of the patient has improved or deteriorated since first seen.	(35 Seconds)
Treatment	Treatment given.	(45 Seconds)

Table 13.1 Handover Tool

The risks and benefits of transferring a patient must be carefully weighed. Technical risks include physiological deterioration, equipment malfunction, and the dislodgement of drips, drains, or tubes. Physically moving the patient introduces significant challenges for the medical team, such as the potential for broken communication loops, distractions from monitor parameter changes, and loss of situational awareness.

When moving between departments, the team's access to emergency drugs and equipment is confined to what can be carried in grab bags or on the transport platform. Decisions regarding the most suitable transport modality and the composition of the transfer team are critical during inter-hospital transfers. Logistical considerations are vital to ensure the transfer does not negatively impact ongoing resuscitation efforts, and strategies to mitigate this risk must be contemplated. Pre-planning personnel and equipment details is crucial.

Organizing a transfer, possibly with a team not previously involved in the patient's care, and selecting the transport modality, presents risks of distraction and loss of situational awareness. Effective communication is imperative throughout the process. The team must strategize how to manage all aspects of the transfer with the resources at their disposal.

High Performance Trauma Team

The organization of a modern trauma team is crucial for the successful management of trauma. It involves well-coordinated prehospital care and information management, followed by a transfer to a well-organized and prepared trauma resuscitation suite (TRS) or operating room (OR). During trauma resuscitation, teams typically follow hospital protocols derived from Advanced Trauma Life Support management protocols. Modern trauma teams often have members with dedicated roles performing specific patient-care tasks simultaneously. This horizontal structure, while more efficient and conducive to rapid resuscitation, demands excellent team coordination, leadership, and organization. Research in advanced trauma units has underscored the challenges in achieving effective teamwork, particularly noting breakdowns in team dynamics under stressful conditions.

Trauma teams are usually composed of 5 to 10 members from various clinical disciplines. Traumatologists, who are often general surgeons, anesthesiologists, or emergency medicine physicians, may act as team leaders, first responders, or fill other roles within the team. Airway management is typically handled by anesthesiologists or emergency physicians, assisted by respiratory therapists. The team may also include specialized trauma nurses, pharmacists, radiological technicians, and other support staff such as laboratory technicians and orderlies, along with residents and medical students. Roles are predefined, with specific tasks allocated to each member, and even the physical setup around the trauma patient in the trauma resuscitation room or suite is usually predetermined.

In general, medical teams, composed of a multidisciplinary array of members, may come together for a single clinical event, such as a particular surgical procedure, or for a brief, defined period, often around a month. It's common for some team members to be permanent (like those in the emergency department), while others, such as respiratory therapists, pharmacists, and anesthesiologists, may join on a temporary, as-needed basis. Consequently, certain individuals may seldom have the chance to collaborate. This situation is also prevalent in trauma teams, particularly due to the demanding nature of trauma care. Additionally, in academic medical centers, where trainees form a significant part of the trauma team, there is frequent rotation on and off the service.

The Trauma Team Leader

The duties of a resuscitation team leader can involve executing specific tasks, like carrying out primary and secondary surveys. Nevertheless, with enough staff, the leader should transition to a supervisory role as soon as possible, focusing on task prioritization, delegation, and monitoring the team's and patient's progress during resuscitation. Evidence suggests that trauma teams perform suboptimally when the leader is heavily involved in procedures instead of allocating them to other team members.

The responsibilities of a Trauma Team Leader include:

- Thoroughly understanding the job, such as mastering the ATLS guidelines.
- Communicating clearly and effectively.
- Improving the team's communication.
- Encouraging teamwork through concrete actions.
- Keeping the team's goals and methods relevant and focused.

- Expanding the team's knowledge and unified expectations.
- Building commitment, confidence, and trust.
- Staying positive and supportive, particularly in challenging situations.
- Recognizing and addressing both personal and team limitations.
- Enhancing the abilities of each team member and the team collectively in all aspects: technical, functional, problem-solving, decision-making, interpersonal, and teamwork.
- Handling relationships with external parties and eliminating barriers.
- Providing chances for others to develop into leadership positions.
- Setting an example for others to follow.
- Valuing team achievements and discouraging counterproductive individualism.
- Offering constructive criticism and chances for skill development.

Trauma Team Members

Effective resuscitation and trauma recovery necessitate a readily available multidisciplinary team skilled in assessing and treating critical injuries. The trauma team leader collaborates closely with other trained specialists in trauma care. All vital team members, such as those in trauma surgery, anesthesiology, surgical critical care, neurosurgery, orthopedic surgery, interventional radiology, and blood banking, must be accessible around the clock to deliver optimal care and fulfill the criteria of a level-1 trauma center.

The primary focus of trauma resuscitation includes managing the airway, breathing, circulation, and hemorrhage control. While the team leader should be aware of these objectives, it is more efficient to assign the management of each to different members. For instance, the anesthesiologist, who is highly trained in managing the airway and evaluating breathing, and a surgical assistant, designated to control bleeding, while other members set up intravenous lines, chest tubes, etc. Although the assistants have the ability to work independently, the resuscitation process is most effective when the team leader supervises each member's actions.

Experienced professionals in trauma management provide superior care compared to less experienced clinicians. In busy trauma centers, seasoned professionals both demonstrate and instruct the proper methods to students and trainees.

Project	Status Related files Notes
Surgeon/team leader	•Initial assessment and survey •Coordinates team activities •Performs procedures
Anaesthetist	•Airway management •Intubation •Ventilation •Performs procedures
Primary nurse	•Calls alert •Records vital information •Assists with procedures of surgeon
Emergency physician/ physician assistant	•Records vital signs •Venous access/draws blood •Inserts urinary catheter •Assists performed procedures
Neurologist	•Neurological evaluation
Radiologist	•Performs FAST if needed •Reads films •Prepares CT
Secondary nurse	•Assists with airway management •Places monitoring devices •Sets up ventilator •Brings blood •Carries blood samples •Prepares transport

Table 13.2 Trauma Team Members Roles and Responsibilities

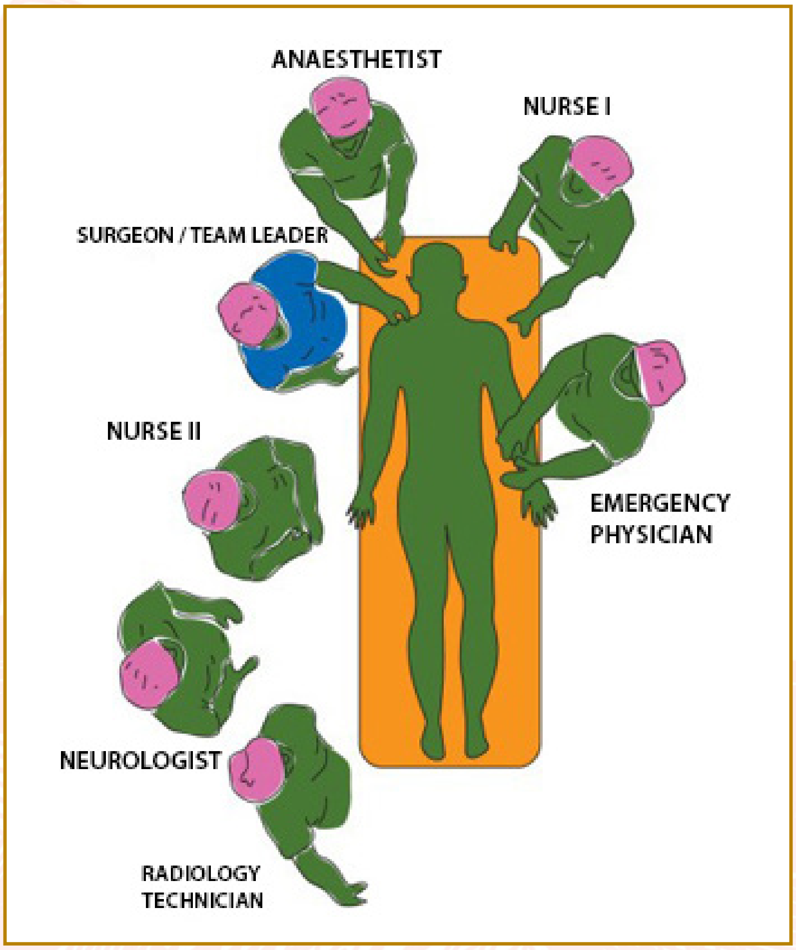


Figure 13.1 Trauma Team Members Positions

Intra-hospital transfer of critically ill patients includes transfer of patients from ED to ICU, ICU to radiology, ICU to theater, and ICU to ward.

Regardless of the final destination, the principles of transport of critically ill patients are the same.

These can be thought of in terms of the 3 P's:

1. Planning.
2. Personnel.
3. Properties.

Planning

This includes determining the reason, risks and benefits of the transfer by assessing the clinical status of the patient and if necessary making changes and / or asking for senior staff assistance.

Planning also includes communication with the receiving end. Give them the estimated time of arrival (ETA) and make sure that they are ready to receive the patient and are aware of the patient's needs e.g. oxygen, ventilator, power points, infusion pumps, etc.

As intra-hospital transfers are usually of short duration, a point can be made of removing all the unnecessary equipment (NG feed, CVP monitor, excess lines) so that you do not get lost in the maze of lines and tubes.

Personnel

The personnel required for the transfer depend on the patient to be transported.

If a medical escort is required, the doctor is in charge of the transfer.

Indications for a medical escort are:

- Patient with a potential airway problem
  - intubated
  - tracheostomy with ventilatory support.
- Patient with potential cardiovascular instability.
- Nursing staff worried about the patient.

Properties

Dedicated equipment for transport must be checked and functional.

The level of monitoring required for the transport of the patient depends on the patient's stability. For unstable patients the level of monitoring should be as comprehensive as it is in ICU, while for the stable patient no monitoring may be required e.g. patient going to the ward.

Basic monitoring devices are an ECG, non-invasive BP, and a pulse oximeter.

Equipment required for intra-hospital transfer is:

- Oxygen cylinder at least ¾ full.
- Airway and intubation equipment.
- Manual self-inflating ventilation bag.
- Suction devices.
- Emergency drugs, analgesics, sedatives, and muscle relaxants.
- Warmed crystalloid +/- colloid, blood.
- Infusion pumps. These must be charged and power cord available to plug in the wall.
- Defibrillator if there is a potential for arrhythmias.
- Chest clamps if underwater chest drains are present.
- Notes, x-rays, request forms, consent form.

Intra-hospital transfer of critically ill patients with little physiological reserve may have a negative outcome for the patient and in these patients there must be a good reason for the transport. To make the transfer as smooth as possible, preparation is essential and ask for senior staff advice and/or assistance.

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