SAFETY

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SIMULATION APPROACH FOR EDUCATION AND TRAINING IN EMERGENCY

Traumatic Emergencies

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Summary

Introduction

Trauma remains the leading cause of death in persons 1 through 44 years of age in developed countries. According to current information from the World Health Organization (WHO) and the Centers of Disease Control and Prevention in the US (CDC), 5.8 million people die every year from unintentional injuries and violence. Therefore, it is essential to avoid preventable deaths as well as to diminish associated morbidity by means of early appropriate care.

Mortality due to trauma injuries is distributed in three peaks. The first peak occurs within seconds to minutes of injury. During this period, deaths generally result from severe brain or high spinal cord injury or heart/large blood vessels injury. This period comprises 50% of trauma deaths. Only prevention can significantly reduce this peak of trauma-related deaths. The second peak, which includes the 10% of deaths, occurs within minutes to several hours following trauma. Deaths in this peak are usually due to severe bleeding, brain swelling or hypoxia. This is known as “the golden hour of care” after injury, and it is characterized by the need for rapid assessment and resuscitation. According to necropsy studies, 85% of deaths during this phase could be avoided within an earlier and more effective assistance. Airway obstruction is the most common cause of preventable death. The third peak (40% of deaths) occurs several days to weeks after injury. It is usually due to sepsis and multiple organ system dysfunctions. The outcome in this clinical situation is related to the speed and quality of the provided care in the previous stages. Analyzing mortality by cause, the main cause of death is brain trauma (50%), followed by thoracic trauma (25%) and abdominal trauma (12%).

Trauma care systems must include an early prehospital assistance by highly qualified personnel, rapid transfer to an appropriate hospital, preferably to verified trauma centers, adequate hospital care based on established protocols to care for injured patients and rehabilitation of the patient till his/her reintegration to society. The development of standardized trauma training is the cornerstone of trauma care systems improvement. The Advanced Trauma Life Support® (ATLS®) program was introduced in the 1980s to address the need for higher-quality trauma care. It has been proven to be useful for increasing trauma survival and is widely attended around the world today. Its principles include rapid and accurate patient assessment, resuscitation according to priority, determination of the resources and capabilities needed for the patient, appropriate arrangement for a patient´s transfer and assurance that the optimal care is provided and that the level of care does not deteriorate at any point during the evaluation, resuscitation, or transfer process. Therefore, the content of this chapter is based on the ATLS® guidelines.

Initial assessment and management

A rapid and systematic approach is essential to assess injuries and set up lifepreserving therapy in trauma patients. Recommendations of the Advanced Trauma Life Support® (ATLS®) course are considered the “gold standard” for initial assessment and management, including the following elements:

- Preparation, structured handover and triage
- Primary survey (ABCDEs) with simultaneous resuscitation of patients with life-threatening injuries
- Adjuncts to the primary survey

- Consideration of the need for patient transfer
- Secondary survey (head-to-toe evaluation and patient history)
- Adjuncts to the secondary survey
- Continued post-resuscitation monitoring and reevaluation
- Definitive care
- Preparing for the future

Primary survey following the ABCDE-approach starts in the trauma scene and it must be repeated frequently during the transfer to the hospital. Both primary and secondary surveys must be constantly reevaluated to identify any change in the patient's status that indicates the need for additional intervention.

Preparation, structured handover and triage

Preparation for trauma patients occurs in both the prehospital and hospital settings. The prehospital setting is the scene where the trauma takes place, and its conditions can be variable. In the prehospital phase, an adequate assistance team is crucial, including the healthcare and support staff. In this phase, providers should perform the primary survey, prioritizing airway maintenance and breathing, control of external bleeding and shock, immobilization of the patient, and immediate transport to the closest appropriate facility, preferably a verified trauma center. It is important to minimize scene time, as well as to obtain and report information regarding time of injury, events related to the injury and patient history if possible. The prehospital system should notify the receiving hospital before patient transfer to allow that all necessary personnel and resources are available at the time of the patient's arrival.

The hospital phase starts with the structured hand-over between prehospital providers and those at the receiving hospital (see Table 1) and should ensure that all important information is available to the designated team-leader and also to the entire team. The critical aspects of hospital preparation include the setup of an adequate area for trauma assessment and resuscitation, the verification of the function and organization of the resuscitation equipment and monitoring devices, and the existence of a protocol to assure coordinated assistance and prompt responses by laboratory and radiology personnel. Triage and rapid stabilization of patients in the hospital phase is important if transfer to verified trauma centers is necessary.

Introduction of teams	Name and role of members transferring and receiving information
Patient identification	Name and age
Brief summary of the trauma (one sentence)	E.g., "Pregnant woman hit by motorcycle at 20 km/h"
Biomechanics of the accident	Type of accident (traffic, precipitation, stab/firearm wound, thermic trauma, etc.) Accident sequence Risk factors (speed, deaths in the accident, vehicle deformation, weather conditions, etc.) Presence of witnesses
ABCDE	Description of any lesion found according to the ABCDE approach Severity, vital signs Treatment administered (drug, dose and time) and response Recommendations (if applicable)
Medical history	Allergies, relevant diseases, chronic medication, etc. Time of last intake
Physical transfer	Recommendations/limitations
Contact person	Name, relationship, phone, information given, sensitive information
Personal belongings	Relevant belongings Place/person who keeps them

Table 1. Example of structured hand-over. Hospital Clínic of Barcelona (Spain) abbreviated protocol

Triage involves sorting of patients based on the resources required for treatment and the resources that are actually available. The order of treatment is based on the ABC priorities (airway with cervical spine protection, breathing, and circulation with hemorrhage control). Priority criteria also include the severity of injury, ability to survive, and available resources.

The trauma leader should prepare the team before patient arrival, receive the handover ensuring a safe transfer of information, direct the team and respond to information, preferably without performing clinical procedures and guiding the debriefing afterwards. All trauma team members should have experience in trauma resuscitation and training in Crisis Resource Management and communication strategies, since it has been proven that they are some of the most important causes of failures in critical patient care. Each of the members should know and effectively perform their roles in trauma care following the leader directions. It is important for all the members to listen to the handover. They should assess the patient and communicate with the leader about the

findings. Team members may be asked to perform certain procedures. They also must keep the leader aware of any difficulty or variation in patient state.

Primary survey with simultaneous resuscitation

Assessment of the patient´s injuries must be done quickly and efficiently. Management consists of a rapid primary survey with simultaneous resuscitation of vital functions, a more detailed secondary survey, and the planning of definitive care. The primary survey encompasses the ABCDEs of trauma care and identifies life-threatening conditions (see Figure 1). The sequence must be followed orderly and next level cannot be approached if the previous level has not been checked:

• Airway maintenance and cervical spine immobilization

• Breathing and ventilation

• Circulation with hemorrhage control

• Disability (assessment of neurologic status)

• Exposure and Environmental control

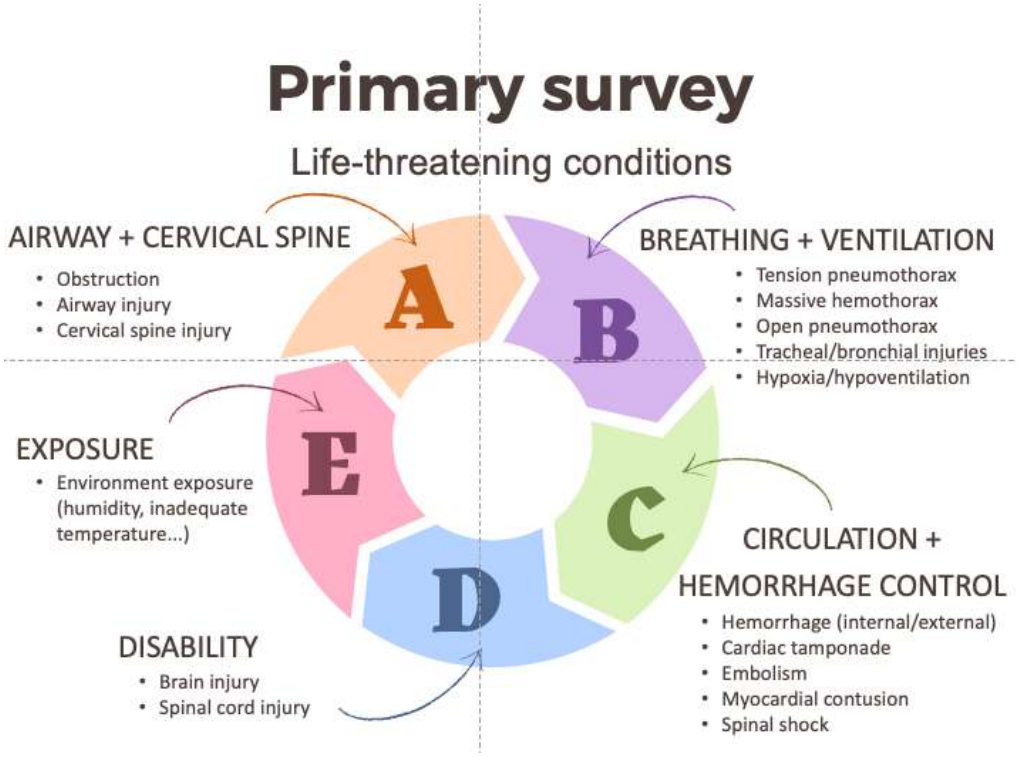

Figure 1. Primary survey: life-threatening conditions

Clinicians can quickly assess A, B, C, and D in a trauma patient by asking the patient for his or her name, and asking what happened. An appropriate response suggests that there is no major airway compromise (i.e., ability to speak clearly), breathing is not severely compromised (i.e., ability to generate air movement to permit speech), and the level of consciousness is not markedly decreased

(i.e., alert enough to describe what happened). Failure to respond to these questions suggests abnormalities in A, B, C, or D that require urgent assessment and management. Life-threatening conditions have to be identified as soon as possible and treated although it may not be possible to identify the specific injuries in this phase. Figure 2 and Figure 3 respectively summarize the main clinical signs that should be explored in the trauma patient and the treatment of the main injuries to rule out in the primary survey.

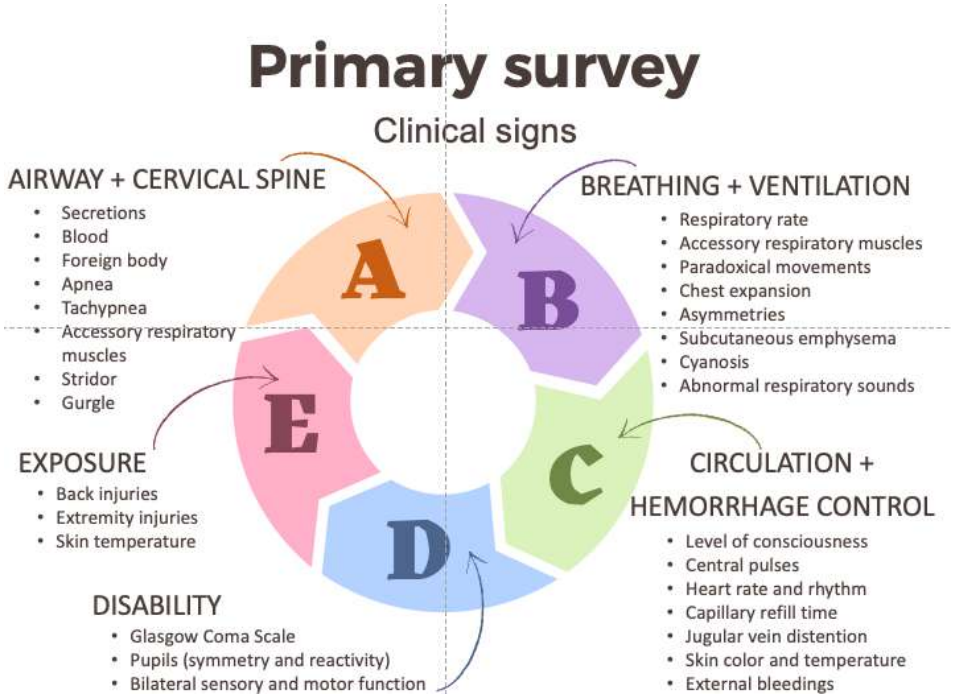

Figure 2. Primary survey: clinical signs

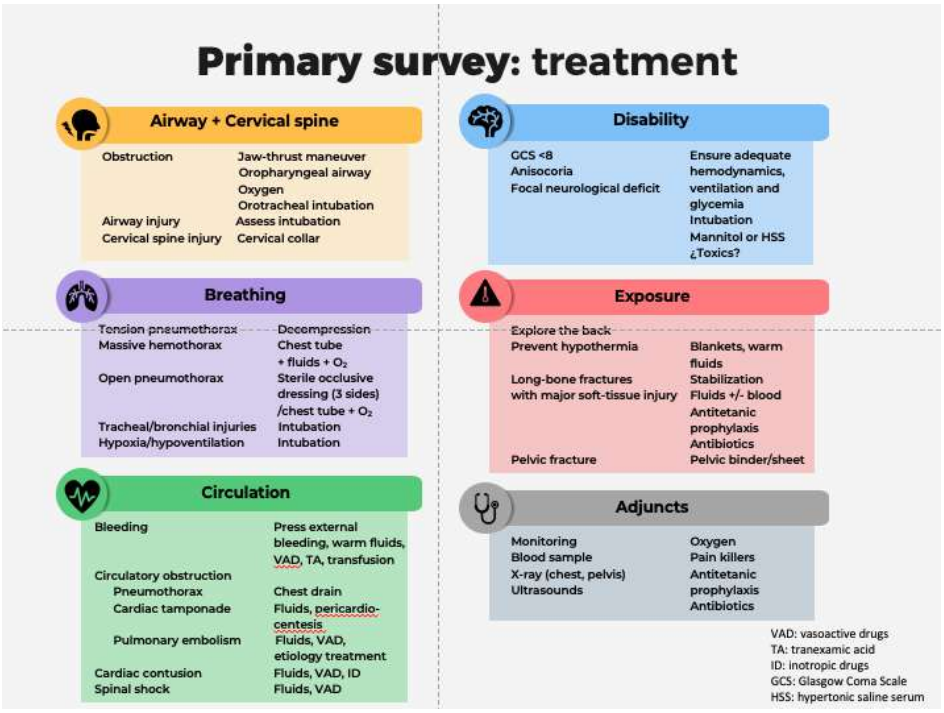

Figure 3. Primary survey: treatments

Airway maintenance and cervical spine immobilization

Airway obstruction is frequent in the trauma patient and one of common causes of preventable death. The main mechanisms of airway obstruction include posterior tongue drop due to an altered level of consciousness or facial trauma, foreign bodies such as teeth, vomit or blood or direct airway injury. Repeated airway patency assessment is recommended by clinical examination. Symptoms such as stridor, tachypnea, use of accessory respiratory muscles or apnea may indicate an airway obstruction.

However, airway patency only can be assured by the patient when he/she is conscious and able to communicate verbally. When the patient is unconscious, airway patency may be compromised. The jaw-thrust maneuver, mouth exploration, aspiration of oral secretions and foreign body removal are initial procedures that may resolve airway obstruction. If the patient maintains spontaneous effective ventilation and has no gag reflex, the placement of an oropharyngeal or nasopharyngeal airway can be helpful, at least temporarily. Placement of a definitive airway is mandatory if there is any doubt about the patient's ability to maintain airway integrity, in patients with an altered level of consciousness (Glasgow Coma Scale score of 8 or lower), in patients with unresolved airway obstruction, and in case of apnea, hypoxemia, cardiac arrest or hemorrhagic shock. If tracheal intubation is necessary and cannot be achieved, a surgical airway (eg, cricothyroidotomy) should be considered.

Neurologic examination alone does not exclude cervical spine injury. It is considered that all trauma patients may have a spine injury, especially when injuries above the clavicle are present. Therefore, a member of the team must manually restrict motion of the cervical spine and a cervical collar must be placed. Any maneuver to assess or manage the patient's airway must protect the cervical spine from excessive movement.

Breathing and ventilation

Airway patency alone does not ensure adequate ventilation. Frequency and quality of ventilation must be checked. To properly assess adequate ventilation, exposure of the patient's neck and chest is needed. Visual inspection and palpation are essential to assess chest expansion, detect asymmetries, paradoxical or inverse movements, emphysema or use of accessory muscles. Auscultation should be performed to ensure gas flow in the lungs. Injuries that significantly impair ventilation in the short term include tension pneumothorax, massive hemothorax, open pneumothorax, and tracheal or bronchial injuries. These injuries should be identified during the primary survey and often require immediate attention to ensure effective ventilation. In all cases, besides providing an effective ventilation, it is essential to administer supplemental oxygen at high flow and concentration. A pulse oximeter should be used to monitor hemoglobin oxygen saturation. Other thoracic injuries such as simple pneumothorax, fractured ribs or pulmonary contusion can compromise ventilation to a lesser degree and are usually identified during the secondary survey.

Circulation with hemorrhage control

Hemorrhage is the predominant cause of preventable deaths after injury, being the cause of 30% of deaths. Rapid identification of hemodynamic status and control of the hemorrhage are essential steps in the management of trauma patients. Once tension pneumothorax has been excluded as a cause of shock, blood loss must be considered the cause until proven otherwise. Clinical signs of hemorrhage include paleness, cold and clammy skin, delayed capillary refill and weak pulse, as well as oliguria and impaired mental status. Tachycardia is usually present, but it also can also be a consequence of pain or agitation. Arterial pressure may not reflect hypovolemia until a blood loss of about 25%, especially in young patients. An external bleeding should be identified and controlled during the primary survey by direct manual pressure on the wound. Tourniquets are not recommended because of the risk of ischemic injury, excepting for uncontrolled bleeding from a traumatic amputation or the bleeding cannot be stopped otherwise. Other sources of bleeding are usually identified by physical examination and imaging in the hospital setting. Early management of hemothorax or fracture stabilization is mandatory, though definite management may require surgical or radiologic treatment.

Vascular access must be established and replacement of intravascular volume rapidly initiated. Placement of two large-bore peripheral venous catheters is recommended. If it is not possible, an intraosseous catheter should be considered for fluid administration. A central venous catheter or venous cutdown are second line options. Blood loss can be estimated depending on the patient's injuries (i.e., 1000-2000 ml for pelvic fracture, 500-1000 ml for femur fractures, 500 ml for a hematoma 8 cm in diameter, etc). Intravenous fluid therapy with crystalloid must be initiated if hypovolemia is suspected. All intravenous solutions should be warmed with fluid warming devices (i.e., 37 to 40 ºC). However, the infusion of more than 1.5L of crystalloid has been shown to be associated with increased mortality in trauma. For this reason, the early use of blood products is advocated. Massive transfusion, defined as the transfusion of more than 10 units of blood in 24 hours, or more than 4 units in one hour, should be used if needed. Coagulopathy is not uncommon in severely injured patients. Following the results of several important trials, tranexamic acid is now recommended within 3 hours at a loading dose of 1g iv followed by 1g infused over eight hours, even started in the prehospital setting. Transfusion protocols with predefined low ratios of blood components can attenuate coagulopathy progression. In trauma patients a hemoglobin level of 10

g/L allows an adequate oxygen transport with an optimal blood viscosity. Vasoactive drugs may be necessary when volume and blood substitution (erythrocyte mass restoration) are not enough to maintain tissue perfusion.

Disability (Neurologic Evaluation)

Neurologic assessment should include level of consciousness, which is already evaluated during the airway assessment. The Glasgow Coma Scale (GCS) is a simple and rapid method to evaluate the level of consciousness. The motor score of the GCS should be evaluated even if the patient has been sedated as it correlates with outcome. Pupillary size and reaction and evaluation of any focal neurological deficit should be determined. Brain herniation may be suspected in patients presenting a GCS <8 (or a sudden deterioration of 2 or more points), anisocoria and/or a focal neurological deficit, once hypoxemia and shock are excluded or treated. Treatment with mannitol or hypertonic saline serum should be started when other possible causes like hypoglycemia, alcohol, narcotics, and other drugs are excluded as the reason for an altered patient's level of consciousness. Alteration of the level of consciousness requires reevaluation of the patient´s ABC: airway, oxygenation, ventilation and perfusion status. Also an impaired movement, weakness or an impaired sensitivity of the extremities, as well as pain in the back could be symptoms of a possible spine injury.

Exposure and Environmental Control

All trauma patients must be undressed and exposed to facilitate a thorough assessment to identify relevant, overlooked injuries. The back of the patients should also be examined after careful immobilization of the patient with restriction of spine motion. After this assessment patients should be covered and kept warm to prevent them from hypothermia. The temperature of the ED area should be increased, and fluids must be heated before administration.

After any (major) procedure (e.g., intubation, chest drain ...) and any deterioration reassess the patient following the ABCDE-approach to identify any new problems which could require medical attention and need for further actions.

Adjuncts to the primary survey

Some clinical measurements and/or monitoring should be obtained during or after performing the primary survey. Continuous electrocardiography, pulse oximetry, blood pressure monitoring, carbon dioxide (CO2) monitoring, assessment of ventilatory rate, and arterial blood gas (ABG) measurement are some of them. Monitoring of these physiologic parameters is useful to guide assessment and evaluate the adequacy of resuscitation. Urinary catheters can also be placed to monitor urine output and assess for hematuria, only when a first complete ABCDE-run is finished. Other helpful tests include blood lactate, x-ray examinations (e.g., chest and pelvis), sonography (FAST and eFAST: extended focused assessment with sonography for trauma), and – when not available or ambiguous - diagnostic peritoneal lavage (DPL). These adjuncts to the primary survey must be repeatedly assessed and reevaluated depending on the patient's status.

Radiographic assessments are important adjuncts to the primary survey. Routine chest and pelvis x-rays must be performed in the resuscitation area to discard life-threatening injuries or pelvic fractures, respectively. Cervical x-ray to detect vertebra fractures or displacements does not always

provide a definitive diagnosis. FAST and eFAST are useful tools to rapidly detect intraabdominal blood, hemothorax and pneumothorax, though their use depends on the personnel´s skill and experience. Obesity, subcutaneous emphysema or intraluminal bowel gas are also limitations of these techniques. In some trauma centers, the CAT scanner is placed in the resuscitation bay and used as a stretcher for the primary survey.

Considerations of the need for patient transfer

Need to transfer the patient to another area (e.g., operating room) for immediate treatment or even another hospital (e.g., level 1 trauma center) for definitive care must be rapidly determined, usually during the primary survey. See Figure 4. Once the patient is being stabilized and transfer can be safely performed, it should not be delayed. Communication between the referring and receiving centers is essential. See Table 2.

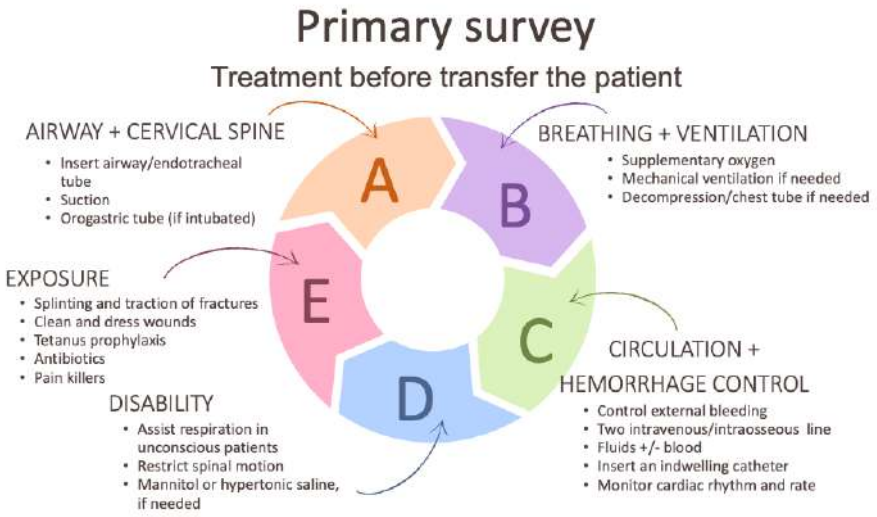

Figure 4. Primary survey: treatment before transfer the patient

ACRONYM	MEANING	INFORMATION TO PROVIDE
A	Airway	Any problem identified and treatment given
B	Breathing	
C	Circulation	
S	Situation	Patient name and age Referring facility Referring physician and nurse Indication for transfer IV access site / IV fluid and rate Other interventions
B	Background	Event history AMPLE assessment - Allergies - Medications currently used

		- Past illnesses/Pregnancy - Last meal - Events/Environment related to the injury Transfusion Treatment (data and time) Imaging (attach file or copy if necessary) Splinting
A	Assessment	Vital signs Exam findings Response to treatment
R	Recommendation	Transport mode (vehicle and level of care) Needed assessment and intervention during transport

Adapted from ATLS ® Advanced Trauma Life Support ® 10th edition

Table 2. An example of Interhospital hand-off transfer form: ABC-SBAR

Secondary survey

The secondary survey is a complete evaluation of the trauma patient, including history and physical examination, and reassessment of vital signs. See Figure 5. It does not begin until the primary survey is completed, and resuscitation has been performed. However, the secondary survey may be initiated if personnel are available, while other team members attend the primary survey. Each region of the body is completely examined to detect any unnoticed injury in the primary survey. See Figure 6.

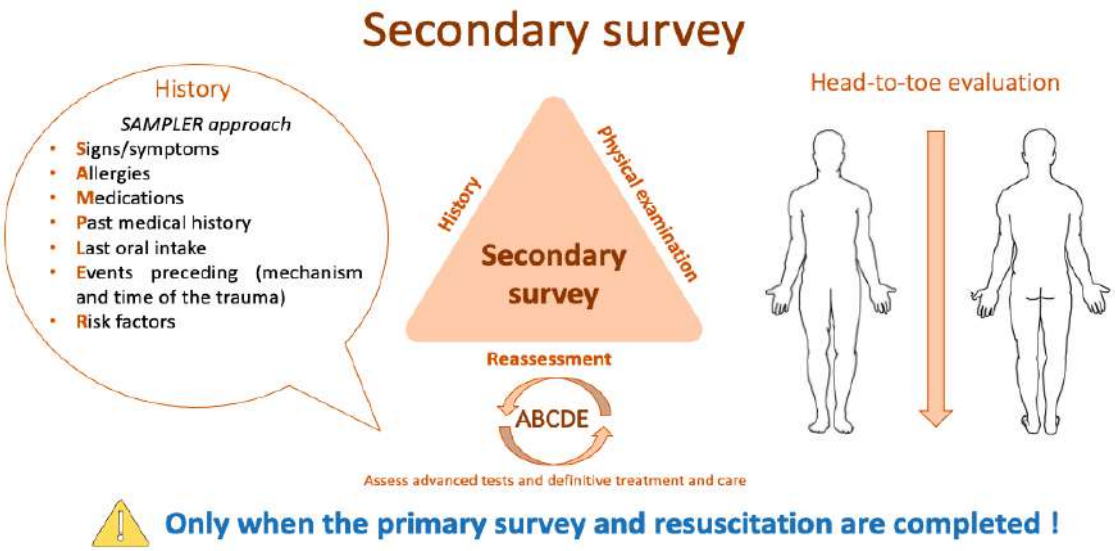

Figure 5. Secondary survey

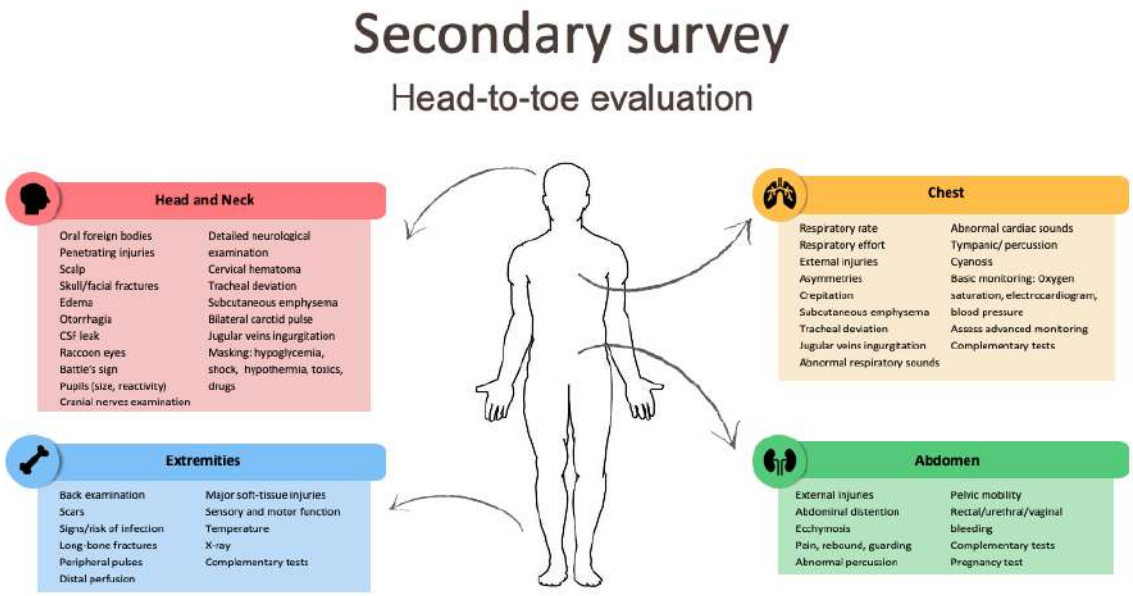

Figure 6. Secondary survey: Head-to-toe evaluation

History

Assessment should include a brief history of the patient and the injury itself, mechanism of injury, and time of the trauma. Prehospital personnel, injury witnesses and family can usually contribute to this information. Knowledge of the mechanism of the injury can help to understand the patient's state and anticipate further injuries. Asking about allergies, current medication, illnesses, last meal and events related to the injury is essential in the patient's assessment.

Physical examination

It includes a complete examination of the body from head to toes.

Head and face: All the head must be examined for any injuries or fractures. Otorrhea, periorbital hematoma, mastoid hematoma can be signs of basal skull fracture. Scalps if present must be stitched rapidly as they may cause important blood loss. Eyes should be examined to assess visual acuity, pupillary size and reactivity, hemorrhage or penetrating injuries, and ocular mobility. Maxillofacial structures injuries that do not imply airway obstruction or major bleeding may be assessed and treated lately. Assessment involves palpation of bony structures, assessment of oral cavity and soft tissues.

Neck: Cervical spine injury may be presumed if maxillofacial or head trauma are present. Cervical mobility must be restricted if spine injury is suspected. Visual inspection can detect tracheal deviation or use of accessory respiratory muscles; palpation is important to assess painful points, tissue deformation or edema, subcutaneous edema or carotid pulse asymmetry. Palpation of the cervical spine can also lead to unnatural alignment or deformities.

Chest: Chest examination includes inspection, palpation, auscultation, percussion and a chest x-ray. Inspection of the chest is useful to evaluate some injuries, identify tracheal deviation and abnormal

movement of the chest wall. Palpation of the entire chest cage must be performed. Painful areas may indicate bone fractures or other injuries. Crepitation may suggest rib fractures and pneumothorax. Auscultation of the chest and in the armpits is useful to identify pneumothorax or hemothorax, which can be confirmed by eFAST or x-ray. Cardiac tamponade comes along with distant heart sounds and decreased pulse pressure.

Abdomen: Abdomen examination may be rather nonspecific and must be repeated over time. Especially in blunt traumas, abdominal examination may be initially normal although significant intraabdominal injuries are present. Abdomen inspection may show abdominal distention, hematoma, or belt injury. Ecchymosis over the iliac wings, pubis or perineal area may suggest pelvis fracture, as well as pain during palpation of pelvic ring. Pain or rigidity of the abdominal wall to palpation may indicate intraabdominal injuries. Percussion can suggest the presence of intraabdominal air or liquid. Lowest rib fractures can be accompanied by liver or spleen injury. FAST is useful to discard intraabdominal blood. When there are equivocal findings or in high energy trauma, an abdominal CAT scan can provide more information, if the patient is hemodynamically stable. Perineum must be assessed for the presence of lacerations, hematomas, urethral bleeding or vaginal injury. Pregnancy tests should be performed on all females in childbearing age.

Extremities: Inspection and palpation of extremities can detect deformities, abnormal movement or tenderness that suggest fractures or other injuries. X-ray will confirm fractures. Impaired sensation, movement or strength may be due to spine and/or nerve injury or ischemia.

Adjuncts to the secondary survey

During the secondary survey, several diagnosis tests should be performed to identify specific injuries. X-ray examinations include an AP chest and pelvic film if they were not already done and spine and extremities films. Complete cervical and thoracolumbar spine imaging must be obtained to discard spine injury. In some centers this evaluation is performed by means of CAT scan instead of x-ray. Restriction of spinal motion must be maintained until a potential spine injury has been discarded. CAT scans of the head, chest, abdomen or spine may be needed. Additional tests such as angiography, echocardiogram, bronchoscopy or others may be necessary depending on suspected injuries. Diagnostic tests that imply patient transportation should be performed only when the patient has been carefully evaluated and his or her hemodynamic status has been stabilized.

Continued post-resuscitation monitoring and reevaluation

Trauma patients must be repeatedly evaluated following the ABCDE-approach as life-threatening injuries and other less severe injuries may become apparent after initial assessment. Continuous monitoring of vital signs is essential. Periodic ABG analyses are necessary in critical patients.

Other important treatments in trauma patients include the relief of pain and anxiety in conscious patients, tetanus and gammaglobulin vaccine if needed, antibiotics in case of open fractures or contaminated wounds, early nutrition or gastric protection.

Definitive care

Definitive trauma care may include support and monitoring in an intensive care unit, admission to an unmonitored unit or operative intervention, as well as specialized diagnostic tests or treatments. It usually involves the availability of qualified personnel and appropriate resources. If definitive trauma care cannot be provided, the transfer of the patient to another facility is mandatory, preferably to a verified trauma center. The decision to transfer a patient will depend on the patient's injuries and the local resources. Transfer should be arranged timely and not be delayed to performing diagnostic procedures. Only immediately life-threatening injuries should be assessed and treated in the initial facility.

Preparing for the future

Once patient care is complete, it is recommended that the entire team that has treated the patient spend a few minutes discussing together how the management of the traumatic patient has gone. The emotional state of the personnel should be assessed, highlighting those actions that have favored the correct outcome of the management and analyzing those points that are susceptible to improvement, all in a calm and trusting environment. This is what is known as "Clinical Debriefing".

Other important aspects are to ensure theoretical and practical training for all healthcare personnel, individually and as a team. For the latter, it has been proven that clinical simulation training improves the coordination and performance of healthcare teams.

Required skills for initial trauma management

1. Assessment and recognition of life-threatening injuries

2. Knowledge of the different types of trauma and injuries associated

3. Primary survey:

    2.1. Airway maintenance:

        - Assessment of airway obstruction and prediction of difficult airway management
        - Recognition of injuries that can compromise airway patency
        - Jaw-thrust or chin-lift maneuver and placement of an oropharyngeal airway
        - Placement of an orotracheal tube/ cricothyroidotomy
        - Motion restriction of cervical spine, cervical collar placement and helmet removal

    2.2. Breathing and ventilation:

        - Assessment of adequate ventilation
        - Bag-mask ventilation

- Chest decompression with a chest tube

2.3. Circulation with hemorrhage control:

- Recognition of hemorrhage and/or shock

- Establishment of the degree of shock (physical examination, blood tests interpretation)

- Establishment of rapid intravenous/intraosseous access (two large-bore peripheral venous catheters) and volume replacement

- Management of external blood loss by direct pressure or tourniquet if needed

- Identification of the source of internal bleeding by physical examination and/or imaging

2.4. Disability:

- Performance of repeatedly neurological evaluation

- Indicate airway assurance if the level of consciousness is altered (GCS below 8)

2.5. Exposure and environmental control:

- Assessment of all the body surface for unadvertised injuries

- Maintenance of patient normothermia

Type of trauma

Healthcare personnel involved in trauma care must understand the mechanisms of injury and the biomechanics that govern the production of these injuries. It is the only way for an early detection of serious injuries that are sometimes initially unnoticed, and the establishment of adequate treatment in appropriate centers.

The injury mechanisms in the traffic accident explain the findings of the injuries produced and therefore it is very important to know the type of accident (frontal impact, side impact, rollover, etc.), as well as whether or not the occupants were traveling restrained by the seat belt, if the air-bags were activated, if they were wearing a helmet in case of a motorcycle accident, etc.

In firearm trauma, the type of projectile, the trajectory, the fragmentation and the impact zone must be taken into account to determine the severity of injuries. In stab wounds, injuries will depend fundamentally on the location and depth of the trauma.

In blast trauma, injuries can be caused by various mechanisms, the most important being by blast wave, penetrating trauma and shock after displacement.

Types of trauma according to body location are briefly described in the tables 3, 4, 5, 6 y 7 (separate document).

	Injuries	Mechanism	Symptoms/signs	Management
Thoracic trauma	*Airway obstruction**	Vomitus, blood, swelling, clavicular dislocation	Estridor, intercostal/supraclavicular retraction, crepitus, desaturation	Airway suctioning Definitive airway
	*Tracheobronchial tree injury**	Rapid deleration (blunt trauma) Penetrating trauma	Hemoptysis, cervical subcutaneous emphysema, tension pneumothorax, cyanosis, air leak after chest tube placement, desaturation	Intubation Selective intubation Surgery
	Pneumothorax (*Tension pneumothorax**)	Air leak from lung injury (blunt trauma or penetrating trauma)	Chest pain, tachypnea, air hunger, tachycardia, hypotension, tracheal deviation away from the side of the injury, absence of respiratory sounds and movement in the side of injury, neck vein distention, percussion hyperresonant, desaturation	Chest decompression: - Chest tube placement - Defect closure on three sides to provide a flutter-valve effect (open pneumothorax)
	Haemothorax (*Massive haemothorax**)	Penetrating wound with blood vessels injury Blunt trauma	Chest pain, tachypnea, air hunger, tachycardia, hypotension, absence of respiratory sounds, neck vein collapse, percussion dull, desaturation	Restoring of blood volume Chest tube placement Thoracotomy
	*Cardiac tamponade**	Penetrating or blunt injuries	Muffled heart sounds, hypotension, distended Veins, FAST	Surgery Pericardiocentesis
	Pulmonary contusion Flail chest	Blunt injury Trauma with multiple rib fractures	Respiratory failure Abnormal chest movement Respiratory failure	Oxygen, prevent volume overload, analgesia, mechanical ventilation
	Cardiac injury	Blunt injury	Dysrhythmias Hypotension Cardiac tamponade Wall-motion abnormality	Monitoring Surgery
	Aortic disruption	Decelerating force	Radiographic signs (widened mediastinum, obliteration of the aortic knob) Hypotension	Surgery
	Diaphragmatic rupture	Blunt or penetrating trauma	Respiratory failure Radiographic signs (elevated diaphragm)	Surgery

Table 3. Thoracic trauma. *Lifethreatening injuries

	Injuries	Mechanism	Symptoms/signs	Management*
Abdominal and pelvic trauma	**Diaphragm injury**	Penetrating wound	X-ray: elevation or "blurring" of the hemidiaphragm, hemothorax, abnormal gas shadow, gastric tube	Surgery
	Duodenal injury	Unrestrained drivers (frontal-impact collisions). Direct blows to the abdomen	Bloody gastric aspirate, retroperitoneal air on x-ray or CT	Surgery
	Pancreatic injury	Direct epigastric blow	CT Surgical exploration	Surgery
	Genitourinary injury	Blunt trauma Deceleration Pelvic fracture (urethral injury)	Gross hematuria Contusion/hematoma in back or flank CT	Non-operatively Surgery
	Hollow viscus injury	Penetrating or blunt trauma(deceleration)	Pain, tenderness Ecchymosis on the abdominal wall (seat-belt sign) or lumbar distraction fracture CT	Surgery
	Solid organ injuries	Penetrating or blunt trauma	Shock Hemorrhage FAST/DPL/CT	Fluid resuscitation Surgery Non-operatively (if haemodynamic stability)
	Pelvic fractures and associated injuries	- AP compression injury - Lateral compression injury - Vertical shear - Combined mechanism	Shock Hemorrhage Bladder/urethra injury X-ray/CT	Fluid resuscitation Mechanical stabilization of the pelvic ring Angiographic embolization Preperitoneal packing

Table 4. Abdominal and pelvic trauma

	Severity	Diagnostic	Initial Management**	Secondary management
Head trauma	**Mild brain injury (GCS 13-15)**	CT scanning* Blood/urine etOH and toxicology screens	History and neurological exam Secondary survey *Admit if: No CT available, CT abnormal, skull fracture, CSF leak, focal deficit, GCS does not return to 15 within 2 hours*	Perform serial examinations until GCS is 15 Rule out indication for CT Perform follow-up CT scan if first is abnormal or GCS remains less than 15 Repeat CT/transfer if neurological status deteriorates
	Moderate brain injury (GCS 9-12)	CT scanning Evaluate for other injuries Type and crossmatch, coagulation studies	Neurosurgical evaluation/transfer History and neurological exam Secondary survey	Serial examinations Consider follow-up CT in 12-18 hours
	Severe brain injury (GCS 3-8)	CT scanning Evaluate for other injuries Type and crossmatch, coagulation studies	Urgent neurosurgical evaluation/transfer Intubation and ventilation for airway protection Treat hypotension, hypovolemia and hypoxia History and neurological exam Secondary survey	Frequent serial examinations with GCS PaCO2 35-40 mmHg Mannitol, brief hyperventilation (PaCO2 no less than 25 mmHg except with signs of cerebral herniation) Address intracranial lesions appropriately

All patients: Perform ABCDEs with special attention to hypoxia and hypotension

*Indication for CT scan:

- High risk for neurosurgical intervention: GCS score less than 15 at 2 hours after injury, suspected open or depressed skull fracture, any sign of basilar skull fracture, vomiting (more than two episodes), age more than 65 years, anticoagulant use.
- Moderate risk for brain injury on CT: loss of consciousness (more than 5 minutes), amnesia before impact (more than 30 minutes), dangerous mechanism.
- It is the preferred method of imaging, although obtaining CT scans should not delay transfer of the patient to a trauma center that is capable of immediate and definitive neurosurgical intervention.

**The primary goal of treatment is to prevent secondary brain injury: enhance cerebral perfusion and blood flow and restore normal oxygenation and ventilation. Hematomas and other lesions that increase intracranial volume should be evacuated early.

Table 5. Head trauma

	Severity*

<table>
<tr><td rowspan="8">Spine and cord injury</td><td>Incomplete
(Any sensation or voluntary movement in the lower extremities, sacral sparing, voluntary anal sphincter contraction, and voluntary toe flexion)</td><td colspan="3">Spine Syndromes:
- Central cord syndrome: Hyperextension. Greater loss of motor strength in the upper extremities with varying degrees of sensory loss.
- Anterior cord syndrome: Cord ischemia. Paraplegia and a bilateral loss of pain and temperature sensation
- Brown-Sequard Syndrome: hemisection of the cord, penetrating trauma. Ipsilateral motor loss and loss of position sense with contralateral loss of pain and temperature sensation</td></tr>
<tr><td>Complete</td><td colspan="3">Sensory/motor level. Respiratory failure.</td></tr>
<tr><td colspan="4">Neurogenic shock: Impairment of the descending sympathetic pathways (T6 and above). Hypotension+bradycardia.
Spinal shock: Flaccidity and loss of reflexes immediately after spinal cord injury (spasticity afterwards)</td></tr>
<tr><td colspan="4">Morphology</td></tr>
<tr><td></td><td>Subtype</td><td>Diagnosis</td><td>Initial management</td></tr>
<tr><td>Cervical spine injury</td><td>-Atlanto-occipital dislocation (flexion and distraction). Death is frequent.
-Atlas fracture (axial loading). Unstable
-C1 rotary subluxation (children). Torticollis.
- Axis fractures. Unstable
- Fractures/dislocations C3-C7. Facets dislocations associated to spine injury</td><td>- CT (first choice)
- Plain radiographic films if no CT available: lateral, AP and open-mouth odontoid views (CT if not appropriate visualization)
- MRI (patients with neck pain and normal radiography)</td><td rowspan="3">Prevent spinal movement (supine on a firm surface without rotating or bending+rigid cervical collar). Align the spine is not recommended if it cause pain

There is insufficient evidence to support the use of steroids in spinal cord injury

Vasopressors if neurogenic shock is suspected

Transfer to an appropriate facility. If there is any concern about the adequacy of ventilation, intubate the patient before transfer

The inability to perceive pain can mask a potentially serious injury elsewhere in the body, such as the usual signs of acute abdominal or pelvic pain associated with pelvic fracture</td></tr>
<tr><td>Thoracic spine injury</td><td>- Anterior wedge compression injuries (usually stable)
- Burst injuries (vertical axial compression)
- Chance fractures (associated with other abdominal injuries)
- Fracture-dislocations (uncommon, complete neurological deficits)</td><td>- CT (first choice)
- Plain radiographic films if no CT available: lateral, AP</td></tr>
<tr><td>Lumbar spine injury</td><td>- Thoracolumbar junction fractures (acute hyperflexion+rotation). Unstable. Bladder and bowel dysfunction+sensory and motor level
- Lumbar fracture. Uncomplete deficits</td><td>- CT (first choice)
- Plain radiographic films if no CT available: lateral, AP</td></tr>
</table>

* All patients with radiographic evidence of injury and all those with neurological deficits should be considered to have an unstable spinal injury.

Table 6. Spine and cord injury

Extremity injuries		**Mechanism**	**Assessment**	**Management**
	Life-threatening extremity injuries (primary survey)			

	Major arterial hemorrhage and traumatic amputation	Penetrating wounds/blunt trauma	External bleeding Loss/changes in pulse quality Expanding hematoma	Manual pressure Tourniquet (if bleeding persists or traumatic amputation) Surgery Early transfer to a trauma center
	Bilateral femur fracture	Significant force	Significant blood loss, severe associated injuries	Early transfer to a trauma center
	Crush syndrome	Compression injury to significant muscle mass	Rhabdomyolysis (metabolic acidosis, hyperkalemia, hypocalcemia, DIC) Myoglobin assay CK>10000 U/L	Intravascular fluid expansion Ion and pH control Alkalinization of the urine Osmotic diuresis
	Limb-threatening extremity injuries (secondary survey)			
	Open fractures and open joint injuries	Communication between the external environment and the bone or joint	Physical examination CT (intraarticular gas)	Intravenous antibiotics (as soon as possible) Remove gross contamination and cover the wound. Tetanus prophylaxis Appropriate immobilization Surgery
	Vascular injuries	Vascular insufficiency associated with a history of blunt, crushing, twisting, or penetrating injury or dislocation to an extremity	Coolness, prolonged capillary refill, diminished peripheral pulses and an abnormal ankle/brachial index CT angiography	Realign the fracture, splint the extremity promptly recognize and emergently treat an acutely avascular extremity. Reduction maneuvers if joint dislocation Early operative revascularization
	Compartment syndrome	Increased pressure within a musculofascial compartment (ischemia and necrosis)	Pain greater than expected, tense swelling, paresthesias, pulse absence	Early fasciotomy
	Neurological injuries	Fractures/dislocations	Deformity Neurological examination	Reduce and splint fracture deformities Reduce dislocations
	Other injuries (secondary survey)			
	Contusion and lacerations	Blunt trauma, penetrating trauma, crush injury	Physical examination (pain, localized swelling, tenderness)	Debridement Limiting function/cold pack
	Joint and ligament injuries	Blunt trauma, penetrating trauma, crush injury	Physical examination (abnormal stress, tenderness, hemarthrosis)	Immobilize joint injuries
	Fractures	Blunt trauma, penetrating trauma, crush injury	Physical examination (pain, swelling, deformity, tenderness, crepitus, and abnormal motion) X-ray films	Immobilization Surgery

Table 7. Extremity injuries

Pediatric traumatism

Traumatisms in the pediatric patient have special considerations compared to the adult patient due to the specific morphological, physiological and social characteristics of the child and therefore, their management requires specific knowledge and skills. In this chapter, some differential aspects in the management of pediatric traumatized patients will be discussed as an example. The objective of this document is to give the reader basic notions of pediatric trauma management. For advanced management, specific training is required.

Causes of pediatric trauma

Injuries are the main cause of mortality in childhood in developed countries, and motor vehicle accidents are the main cause of death at all ages, either as a vehicle occupant or as a pedestrian. Other causes of trauma are falls, submersion, domestic accidents or aggression, among which child abuse is especially relevant for, among other reasons, the high risk of death or serious injury. The incidence of the different causes varies between countries being, for example, firearm injuries relevant in the United States, while in Europe these injuries are marginal.

Characteristics of the pediatric patient

Although the management of pediatric patients is generally similar to the adult ABCDE approach, it is necessary to consider some specific characteristics of childhood:

- Vital signs, ability to metabolize drugs, and circulating volume vary with age and development. Device size, drug dosage, and fluid volume need to be adjusted to the child's age and size. For professionals who do not usually treat children, it is advisable to use cognitive aids such as length-based resuscitation tapes, which provide the child's approximate weight, respiratory rate, fluid resuscitation volume, and a variety of drug dosages.

- Children are especially sensitive to stress and fear and it is important to know how to deal with them. Vital signs and behavior can be altered and make the anamnesis, diagnosis and treatment difficult. For instance, panic can be confused with psychomotor excitement.

- Blunt trauma and multiorgan injury is the rule due to the lower body mass and the higher concentration of organs per unit of body surface compared to the adult.

- The proportionally larger head size favors head injuries, which are the main cause of death in pediatric trauma.

- Chest trauma is the second cause of death. Pulmonary contusion, pneumothorax and haemothorax are the most common injuries in thoracic trauma. Rib fractures are rare, and their presence indicates high-energy trauma.

- Children are more sensitive to hypoxia and hypovolemia, especially the younger children. Early treatment is a priority.

- Children are especially sensitive to hypothermia (the younger, the more sensitive).

- Fractures are less frequent. Bones are in formation and physis can be interpreted as fracture lines in X-rays.

- Exposure to ionizing radiation should be restricted due to its potential carcinogenic effect. X-ray or MRI may be alternatives to CT scan.

- Before transferring the patient to a trauma center, only essential tests to rule out suspected immediate life-threatening injuries should be performed.

- There are scales that help assess the severity of the trauma and the need for referral to a specialized facility. Table 8 shows an adaptation of the Pediatric trauma score. Children with eight or fewer points should be transferred to an adequate facility to provide optimal pediatric care.

- Children have many potential years to live. Consequently, a serious or disabling injury will have social and economic repercussions for the patient, caregivers and society for decades.

ASSESSMENT COMPONENT	**SCORE**		
	+2	+1	-1
Weight	>20 kg	10-20 kg	<10 kg
Airway	Patent	Maintainable (oral/nasal airway, oxygen)	Non-maintainable (intubated, cricothyroidotomy, tracheostomy)
Systolic blood pressure	>90 mmHg*, good peripheral pulses and perfusion	50-90 mmHg*, central pulses palpable only (carotid/femoral)	<50 mm Hg*; weak or no pulses
Level of Consciousness	Awake	Obtunded or loss of consciousness	Coma
Fracture	None	Single and closed	Open or multiple
Skin injury	None	Minor (contusion, abrasion, laceration <7 cm not through fascia)	Major (tissue loss, any gunshot wound or stab wound through fascia)

Adapted from Tepas JJ, Mollitt DL, Talbert JL, et al. The pediatric trauma score as a predictor of injury severity in the injured child. Journal of Pediatric Surgery 1987; 22(1)15. (*) Physiological systolic blood pressure varies with age.

Table 8. Pediatric trauma score.

Child maltreatment

A particularly relevant cause of childhood trauma is abuse. Due to the special vulnerability of the child, it is essential to be attentive to those signs that may make us suspect abuse, and report it to the corresponding authority. Mortality in intentional trauma is higher than accidental, and it is especially important to rule it out in children under two years of age. An important cause of abuse is vicarious violence, where one of the parents exerts violence on the child to indirectly hurt the mother/father, and in some cases can lead to homicide. Table 9 specifies some signs of suspicion.

Table 9. When to suspect child abuse
Repeated visits to the emergency room for different traumas
Multiple injuries at different stays, includes healed fractures
Genital, perianal and oral lesions
Mechanism of injury inconsistent with the child's developmental stage
Long bone fractures in children under three years of age
Skull or rib fractures in children under two years of age
Inconsistency between the caregiver's testimony and the injuries sustained
Incoherence of the story between caregivers/witnesses
Characteristic similar multiple injuries: cigarette burns, bites, rope marks
Traumatism in the child of an abused mother/father (vicarious violence)