Initial Assessment and Management of the Trauma Patient

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On arrival to the hospital, the injured patient requires immediate attention. Severely injured patients often have dramatic presentations, and chaos is apt to ensue among providers if they are not well prepared. A rational and predefined plan for diagnosing and treating the trauma patient is necessary. The standard approach of performing a full history and physical exam, ordering tests, and then providing treatment is not appropriate, as some patients will have succumbed to their injuries during that time. Instead, the initial assessment and management of the trauma patient needs to be expedient, highly ordered, and prioritized to rapidly and reliably diagnose and treat the most immediately life-threatening problems, but also evaluate for occult injuries that could cause major morbidity and mortality if not identified early.

The Advanced Trauma Life Support (ATLS) training program was developed to provide uniformity in the assessment and management of trauma patients. ATLS was first utilized to teach trauma management to rural doctors in the late 1970s [1]. The program was adopted nationally by the American College of Surgeons Committee on Trauma (ACSCOT) in 1980 and has since been taught worldwide and updated to reflect the latest evidence in trauma care [2]. ATLS, now in its 9th edition, is taught to surgeons, emergency medicine physicians, anesthesiologists, nurses, and advanced care providers. This chapter largely reviews the approach taught in ATLS (now in it's 9th edition) [3].

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Pre-hospital and Triage

In many communities, information is provided by emergency medical personnel about a trauma patient prior to arrival to the hospital. Pre-hospital notification allows team members to be alerted, including the trauma surgeon, anesthesiologist, nursing team, and radiology and operating room staff. A team meeting can be held, and preparation can be tailored to specific information provided about a patient. For example, pre-hospital notification regarding a patient with a gunshot wound to the chest and labored breathing would prompt the team to prepare and open a chest tube insertion kit. Finally, pre-hospital notification allows the trauma team to put on personal protective equipment (gloves, gowns, and masks) before the patient arrives. A combative patient can expose providers to substantial amounts of bodily fluids, and the incidence of blood-borne

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Table 1.1 Example of tiered trauma team activation criteria for trauma patient triage

Level 1	*Physiologic criteria:*
	• Impending respiratory failure or intubated
	• Systolic blood pressure $\leq$ 90 mmHg
	– Systolic blood pressure $\leq$ 20 mmHg below age appropriate blood pressure in pediatric patients (age $<$ 15 years)
	• GCS $<$ 10
	• HR $>$ 120
	Anatomic criteria:
	• All penetrating injuries to the head, neck, torso, or extremities proximal to the elbows or knees (excluding minor lacerations)
	• Any penetrating injury with hemodynamic instability
	• Any extremity amputation proximal to the wrist or ankle
	• Crushed, mangled, degloved, or pulseless extremity
	• Pelvic fracture (excluding falls from standing)
	• Two or more long bone fractures
	• Suspected spinal cord injury/paralysis
	• Motor vehicle crash with:
	– Ejection or death of a passenger
	– Intrusion $>$ 12 in. into passenger area
	• Falls $>$ 20 ft ($>$10 ft or 2 $\times$ height in age $<$ 15)
	• Inhalation injury or second- and third-degree burns involving $>$20 % body surface area
	• Transfers from other hospitals receiving blood
	• Discretion of attending physician or nursing
Level 2	*None of the above, and any of the following:*
	Physiologic criteria:
	• GCS $<$ 13
	• HR 100–120
	Anatomic criteria:
	• Any fall above standing height with loss of consciousness or falls $>$10 ft
	• Substantial ($>$20 mph impact) auto-pedestrian, auto-bicycle, motorcycle crash
	• Pregnancy beyond 20 weeks and significant mechanism of injury
	• First- and second-degree burns $\geq$5 % and $\leq$20 % body surface area
	• Discretion of attending physician or nursing
	• Age $>$ 70 years or anticoagulation
Level 3	*None of the above, and any of the following:*
	• Non-emergent consults for trauma not meeting activation criteria
	• Trauma patients with substantial mechanisms being admitted to other services
	• Trauma patients $>$ 24 h
	• Trauma patient transfers not meeting level 1 or 2 criteria

disease is higher in trauma patients than in the general hospital population [4].

Triage of trauma patients is critical to ensure appropriate resource utilization and to decrease morbidity and mortality. When data is available, either pre-hospital or on arrival, patients are typically classified into a three-tiered system of resource utilization, from Level 1 (highest acuity) to Level 3 (lowest acuity) (Table 1.1). Level 1 activation triggers a high resource emergency trauma team reaction, a Level 2 activation results in a moderate resource urgent trauma team response, and Level 3 activation receives a routine trauma team consult. The tiered activations result in greater resources being made available more rapidly when needed. A tiered system of triage and trauma team activation results in better resource utilization

and decreased mortality compared to systems where triage triggers do not exist [5].

Triage of trauma patients can occur based on clinical condition, mechanism of injury, age, or comorbid conditions. Clinical criteria such as vital signs, consciousness level, and ventilation assistance are validated as predictive of mortality [6]. A mechanism of injury such as penetrating trauma to the neck or torso justifies a high level of triage even in the presence of normal initial vital signs and mental status. Variation exists in mechanism criteria among trauma centers. For example, a motor vehicle accident would be considered more concerning in a rural trauma center near several major interstate high-speed highways than in an urban setting where driving occurs at lower speeds on congested local streets. Due to their vulnerability, pediatric and elderly patients warrant special consideration during triage. Patients benefit from appropriate triage and prompt evaluation using the ATLS system.

Primary Survey

Every trauma patient is evaluated using the primary survey, a rapid, reproducible physical exam designed to diagnose and treat immediately life-threatening conditions first. All patients are evaluated for physiologic or anatomic derangements that could lead to early mortality and morbidity. Treatment of problems identified during the primary survey begins without delay, before the survey is completed. The sequence of the primary survey can be remembered with the following mnemonic: "A.B.C.D.E."

Airway (Maintain a patent airway with cervical stabilization)

Breathing (Ensure oxygenation and ventilation)

Circulation (Fluid resuscitation and identify and control hemorrhage)

Disability (Identify any gross neurologic deficits)

Exposure/Environment (Undress patient for complete exam, then prevent hypothermia)

Keep in mind that while the primary survey has a clear order to *priority*, the assessment and treatment of problems identified in the primary survey can and should happen in parallel. If an airway problem is identified at the beginning of the survey, and a decision is made to obtain a secure airway for the patient, the rest of the primary survey should continue while the airway is secured. This is accomplished with a team approach to the primary survey, where multiple care providers perform different parts of the primary survey and report to a team leader who "runs the trauma" by coordinating the effort. This team approach reduces resuscitation time significantly (Fig. 1.1) [7].

Full monitoring of the patient, including an electrocardiogram (ECG) if indicated, as well as the administration of oxygen, intravenous fluid, blood products, or medications as warranted should occur in parallel with the primary survey. This can only be accomplished with a team approach to the primary survey.

The elements of the primary survey must be continually reevaluated in a sequential manner due to the fact that a trauma patient's condition can evolve and deteriorate rapidly. This is especially true if at any point a patient is not responding in an expected manner to resuscitation efforts. Consider this scenario: A patient with a head injury secondary to a high fall is intubated on arrival for poor mental status and an inability to protect his airway. Subsequently, the patient was found to have good breath sounds bilaterally with manual ventilation, as well as normal vital signs and circulatory assessment. Ten minutes later, just prior to CT scan, he becomes progressively hypotensive. The astute clinician returns to the primary survey and notes that the endotracheal tube is still in the same position; however, breath sounds are absent on the right side, and new subcutaneous emphysema has appeared over the right chest wall. On closer examination, the patient's neck veins are now distended, and the trachea appears to be shifted to the left. A right-sided chest tube is inserted to relieve a tension pneumothorax that was exacerbated by positive pressure ventilation after intubation. This example highlights the rapid evolution of a trauma patient's condition

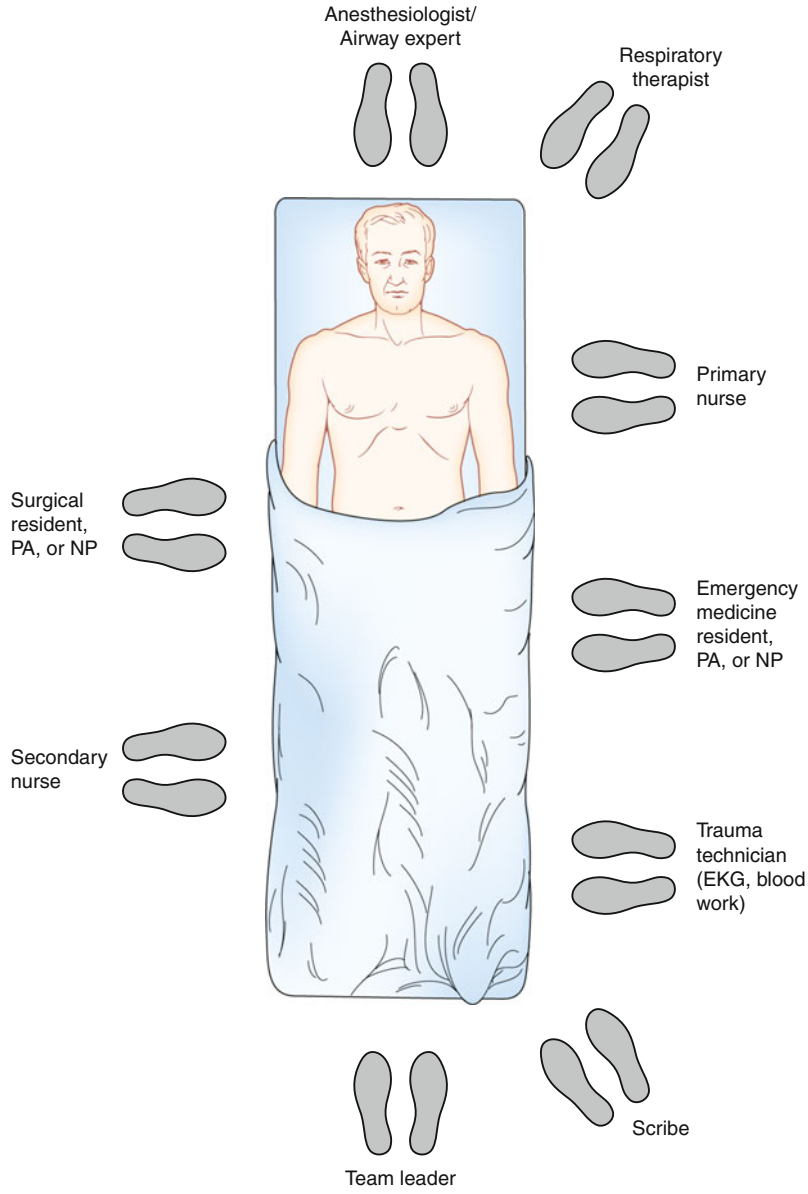

Fig. 1.1 Example of trauma team personnel placement around the bedside of a trauma patient

and the importance of returning to "A, B, C, D, and E" repeatedly during initial management.

Airway

The first priority in the primary survey of the trauma patient is a rapid, but accurate assessment of the airway. Typically, little information is available about a patient's medical history and previous airway management. Trauma patients may have unstable cervical-spine injuries that cannot be immediately evaluated. As a result, any manipulation of the cervical spine may be unsafe. Tilting the head into "sniffing position" to improve airway patency is therefore often contraindicated. Considering the often spectacular presentation of the most severely injured

patients, typically with an unknown medical history, occult injuries, and little time to establish an airway (all while maintaining cervical spine precautions), managing the airway in the trauma patient presents a challenge which requires a specialized skill set.

Some patients will arrive with an advanced airway placed in the field, which may be an endotracheal tube, supraglottic airway (such as a laryngeal mask airway "LMA"), or duel lumen esophageal tube (Combitube^{TM}). It is paramount that this airway be assessed by confirming position, effective ventilation, and adequate airway protection. A supraglottic airway or dual lumen esophageal tube is less secure than an endotracheal tube, and possibly ineffective with regard to ventilation and airway protection. In some cases, an airway placed in the pre-hospital setting will need to be replaced with an endotracheal tube, depending on the provider's assessment of the situation and accompanying risks and benefits.

In the conscious trauma patient, the best means of assessment is to simply ask, "what is your name?" A response given in a normal voice is indicative of a currently intact airway. If the patient is unable to speak, or his or her voice sounds altered, then airway compromise may be present, and more investigation is warranted. Keep in mind that some patients are unable to verbalize for reasons unrelated to airway compromise, such as a language barrier, mental disability, or psychiatric illness. Additionally, some injuries, such as burns, cause progressive airway swelling which can lead to progressive airway compromise even in the presence of an initially normal exam.

In an apparently unconscious or severely intoxicated patient, assessment of the airway starts with a chin lift and jaw thrust to open the pharynx while avoiding manipulation of the cervical spine. The oropharynx should then be examined and cleared of blood, vomitus, and debris by suctioning. A patient who responds vigorously to attempted suctioning may be able to protect his or her own airway. If obstruction is relieved via these simple maneuvers and airway protection is intact, an advanced airway may not be required, and supplemental high flow oxygen via face mask should be provided. In contrast, patients with obvious hoarseness, stridor, retractions, or respiratory distress may need further airway management, and patients with a Glasgow Coma Score of less than 8 or persistent airway obstruction require endotracheal intubation or a surgical airway.

Rapid sequence induction (RSI) and intubation with a cuffed endotracheal tube is the most commonly employed method of securing an advanced airway in a trauma patient. The goal of RSI is to decrease the risk of aspiration. The time between complete loss of airway reflexes and obtaining a secured airway is minimized by simultaneously administering a fast acting sedative/hypnotic agent and a muscle relaxant. When possible, bag mask ventilation is not performed due to the potential for insufflating the stomach and causing aspiration of gastric contents. The benefits of an RSI must be balanced with the risks. In a patient who may be difficult to mask ventilate or intubate, securing the airway after applying topical local anesthetics and using minimal sedation (an "awake intubation") is indicated. Hypotensive patients may not tolerate the loss of sympathetic tone and myocardial depression that accompanies the administration of sedative/hypnotic medications. Comatose patients often do not require additional sedation for laryngoscopy to be performed. In patients with head and neck trauma, visualization of the glottis and establishment of an airway may be impossible via direct laryngoscopy, and use of a specialized device such as a fiberoptic bronchoscope, video laryngoscope, or rigid bronchoscope or emergent placement of a surgical airway such as a tracheostomy or cricothyroidotomy may be necessary. An alternate plan for ventilation should exist for cases in which direct laryngoscopy fails. Agents for blood pressure support should be immediately available.

In the trauma patient, coexisting injuries must be considered. Importantly, cervical spine precautions must be maintained at all times. This is usually accomplished by placing the patient in a rigid cervical collar during or prior

to the initial assessment. This collar is often removed for airway management to provide room for mouth opening during laryngoscopy. When this collar is off of the patient, an individual must be assigned to maintain manual in-line cervical immobilization at all times until the airway is secured and the collar is replaced.

Breathing

Next, the patient's breathing, ventilation, and oxygenation should be assessed, and any life-threatening derangements must be treated. Physical exam, pulse oximetry, and continuous end-tidal carbon dioxide monitoring should be used. Inspection involves noting if breathing is comfortable or labored. Hypoxia can be a cause of confusion and combativeness in a patient. The patient's color is noted (normal, cyanotic, or pale) and the chest wall is observed for normal motion. The chest should be palpated for unstable segments and crepitus. Finally, bilateral auscultation should be performed to determine the presence, symmetry, and quality of breath sounds. Diminished or absent breath sounds on one side is a cause for concern. If the patient is unstable in any way, intervention is warranted emergently.

The most common interventions performed during the primary survey to support breathing are supplemental oxygen delivery, assisted or mechanical ventilation, and tube thoracostomy or chest tube insertion. Supplemental oxygen by face mask is used liberally during the primary survey in spontaneously breathing patients until normal oxygenation can be ensured. Common causes of hypoxic respiratory insufficiency in trauma patients are pulmonary contusion and aspiration pneumonitis. A patient who is hypoventilating can be assisted by bag mask if the patient is able to maintain airway protection. Common causes of impaired ventilation in trauma patients are rib fractures/flail chest, intoxication/drug overdose, and severe head injury. A more definitive airway may be needed in those patients with more profound hypoxic or hypoventilatory respiratory failure. Tube thoracostomy is indicated in patients with decreased or absent breath sounds and hypotension or severe respiratory distress due to a hemothorax or tension pneumothorax.

A hemothorax is the accumulation of blood in the pleural cavity around the lung, which can occur in either blunt or penetrating trauma. The diagnosis is suspected in a patient with diminished or absent breath sounds. In the stable patient, the presence of a hemothorax may be confirmed with a portable chest radiograph. For the patient in distress, a large bore (at least 28 French) chest tube is inserted on the side with diminished breath sounds. Hemodynamic instability or massive hemothorax (an output of greater than 1,500 cm^3 of blood from the chest, less in small or pediatric patients) are indications for an operative exploration to control the source of bleeding. In addition to being diagnostic, chest tube insertion is therapeutic via improving ventilation, relieving tension, and collecting blood that can be autotransfused. Autotransfusion of filtered blood in trauma patients can be a safe alternative to transfusing banked blood [8]; however, filtered blood is inherently depleted of clotting factors and platelets, which may also need to be replaced [9].

A pneumothorax is the presence of air in the pleural cavity around the lung, which can also occur in both blunt and penetrating trauma. The diagnosis and symptoms can be subtle on physical exam if the pneumothorax is small and is often only revealed on chest radiograph or computed tomography scan. Of greatest concern during the primary survey is the presence of a *tension* pneumothorax. Air under pressure in the pleural cavity causes the mediastinum and its contents to shift away from the ipsilateral side of injury towards the contra-lateral side of lower pressure. This can be immediately life-threatening by causing obstruction of venous return to the heart and cardiovascular collapse. While the diagnosis of small (or occult) pneumothorax is difficult on physical exam, the diagnosis of tension pneumothorax should be able to be made at the bedside without imaging. If a patient is experiencing acute respiratory failure or hemodynamic instability with hypotension and

has unilateral diminished breath sounds, one should strongly suspect a tension pneumothorax, and a chest tube should be placed immediately to alleviate the pressure. Other physical exam findings that are suggestive of tension pneumothorax are distended neck veins, subcutaneous emphysema, and tracheal deviation. If a chest tube cannot be safely placed in an expeditious manner, needle thoracostomy is an acceptable alternative, which is performed by inserting an angiocatheter (usually 14 gauge) between the ribs, into the second intercostal space in the mid clavicular line. Although technically simple, needle thoracostomy can cause a puncture of the lung or laceration of a blood vessel (such as the internal mammary artery), therefore it should only be employed in an emergency situation.

An open pneumothorax ("sucking chest wound") is an injury to the chest wall that communicates freely with the pleural space. Inspiration generates negative pressure, pulling air into the pleural space through the wound, potentially causing lung collapse and acute respiratory failure. The definitive treatment is tube thoracostomy (a "chest tube") and repair/dressing of the wound. If a chest tube is not available, however, an alternate treatment is to place a partially occlusive dressing over the wound. The goal of the partial occlusion is to achieve a one-way valve to avoid pulling in air through the wound while allowing an opening for pressure to be relieved, in order to decrease the risk of a tension pneumothorax. This is classically achieved by taping the dressing on three sides to hold the dressing over the wound, but leaving the fourth side free so that air can escape from that side of the dressing (Fig. 1.2).

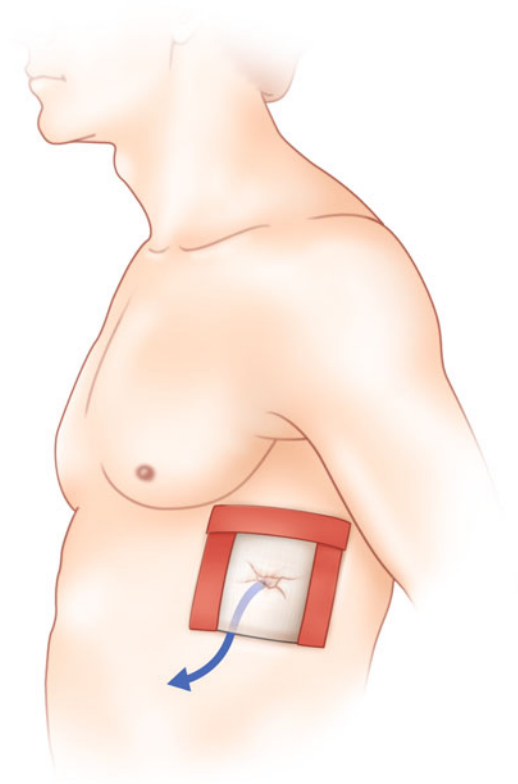

Fig. 1.2 Partially occlusive dressing (taped on three sides only) for open pneumothorax functions as a one-way valve, to relieve any tension, but not allow air to be sucked into the wound

Circulation

After addressing the highest priorities in the primary survey (airway and breathing), circulation must be assessed to determine the presence or absence of shock. Shock is defined as inadequate organ perfusion and tissue oxygenation. In the trauma patient, shock is assumed to be hypovolemic/hemorrhagic and resuscitation begins as soon as vascular access can be obtained. The possibility of neurogenic shock (e.g., spinal cord injury) or cardiogenic shock (e.g., pericardial tamponade) should also be considered. The focus of this segment of the primary survey should be assessing for the presence of shock, determining the cause (usually blood loss) and beginning resuscitation.

Assessment of shock begins with performing a physical exam and evaluating a patient's vital signs. Patients with hemorrhagic shock typically develop derangements in their blood pressure and heart rate that are proportional to the amount of blood loss and degree of shock (Table 1.2). Hemorrhage will lead to a decreased preload, which triggers a compensatory increase in heart rate to maintain cardiac output. Blood pressure will fall as hypovolemia worsens. These changes

Table 1.2 Classes of hemorrhagic shock by ATLS designation for a 70 kg patient [3]

	Class 1	Class 2	Class 3	Class 4
Blood loss (mL)	<750	750–1,500	1,500–2,000	>2,000
Blood loss (%)	<15	15–30	30–40	>40
Heart rate (bpm)	<100	>100	>120	>140
Systolic blood pressure	Normal	Normal	Decreased	Decreased
Pulse pressure	Normal	Decreased	Decreased	Decreased
Respiratory rate (resp/min)	14–20	20–30	30–40	>35
Urine output (mL/h)	>30	20–30	5–15	Negligible
Mental status	Slightly anxious	Mildly anxious	Anxious/confused	Confused/lethargic

vary based on age. In particular, elderly patients have less capacity to increase their heart rate to maintain cardiac output (especially if they are taking beta blockers). Likewise, pediatric patients have an incredible capacity to maintain blood pressure through vasoconstriction. Children can suffer from profound hemorrhagic shock but maintain a normal blood pressure until moments before a cardiac arrest occurs. Sometimes, abnormal vital signs will indicate other types of shock. For instance, patients with blunt cardiac injury may present with arrhythmias, heart block, and bradycardia. Patients with a high spinal cord injury may present with a low heart rate (cardiac accelerator fibers are present from T1 to T4), but may simultaneously suffer from severe neurogenic shock resulting in the vasodilation of peripheral blood vessels.

Signs of poor perfusion include a weak pulse, cool or clammy extremities, dry mucus membranes, pale skin, and confusion. A normal mental status exam confirms the presence of acceptable cerebral perfusion.

In addition to serving as an assessment for the presence of shock, the physical exam can also reveal etiology. A tension pneumothorax or hemothorax, found in a patient with absent unilateral breath sounds, could explain poor perfusion. Abdominal distension, pelvic instability, and long bone deformities can be associated with blood loss. The presence of lacerations and wounds (especially gunshot wounds) should be noted, and if active bleeding is present it should be controlled with direct digital pressure, a proximal tourniquet, stapling, or clips (Raney clips are especially useful for scalp lacerations). Rapidly diagnosing the source of blood loss in a trauma patient is critical for hemorrhage control and should be done in conjunction with the most skilled member of the trauma team.

Resuscitation of the trauma patient should begin as early as possible and often occurs in the pre-hospital setting. The first priority is to obtain vascular access. The standard of care is the rapid placement of two large bore intravenous (IV) lines in the upper extremities. If this cannot be performed in an expeditious manner, alternate vascular access such as an intraosseous (IO) line or central line placement should be performed. In the past, IO lines were used only in pediatric patients, but new designs and insertion devices have made IO access a viable option in adult patients. IO lines can be comparable to central access in the care of trauma patients [10]. The location of intravascular access should be dictated by injuries and suspected sites of blood loss, and severely traumatized extremities should not be used for IV sites when possible. In general, patients with a suspected injury below the diaphragm such as a liver laceration or pelvic fracture benefit from vascular access above the diaphragm (such as an upper extremity peripheral IV, subclavian/internal jugular central line, or humerus/sternal IO line). Similarly, patients with trauma above the diaphragm such as a slash wound to the neck should be provided access below the diaphragm such as femoral central line or a tibial IO line.

In a patient who may be hypoperfused, resuscitation with crystalloid fluids (or blood products in severe cases) should begin immediately after vascular access is obtained. ATLS

recommends starting with an initial bolus of 1–2 L of warmed isotonic IV fluids in adults or 20 mL/kg in pediatric patients [3]. If a patient becomes hemodynamically stable following this bolus and hemorrhage control is obtained, then this may be the only fluid resuscitation that is needed. However, a patient who remains hypotensive after this intervention, or has only a transient response, requires further resuscitation utilizing blood products. Cross-matched and screened blood products are preferred, however, in urgent cases. O negative blood may be used while the team is waiting for type specific blood to arrive.

The goal of resuscitation is to maintain tissue perfusion and homeostasis. Over resuscitation (in particular with isotonic fluids) can lead to complications of volume overload. Aggressive efforts must be made to preserve homeostasis during resuscitation with particular attention paid to the avoidance of hypothermia, acidosis, and coagulopathy, the so-called "triad of death." In particular, coagulopathy can be caused by the simultaneous consumption and dilution (with IV fluids) of platelets and clotting factors. Deliberate attention must be focused on making blood products available in large amounts and ensuring that packed red blood cells, plasma, and platelets are transfused in an appropriate ratio. Most trauma centers employ a massive transfusion protocol (MTP) to be instituted for those trauma patients who require the rapid administration of large amounts of blood products [11]. Recently, substantial literature has supported transfusion of a high ratio of FFP and platelets to packed red blood cells [12, 13], and the components of the MTP have evolved accordingly [14]. While the ideal ratio of plasma and platelets to packed red blood cells, as well as the use of other pro-coagulants is often debated, the mainstay of treatment for hemorrhagic shock continues to be fluid resuscitation with warm crystalloid fluids followed by blood products, and immediate localization and source control of bleeding.

Table 1.3 Glascow Coma Scale scoring system

Eye opening (E)
• 4 = spontaneous
• 3 = to voice
• 2 = to pain
• 1 = none
Verbal response (V)
• 5 = normal conversation
• 4 = disoriented conversation
• 3 = words, but not coherent
• 2 = no words, only sounds
• 1 = none
Motor response (M)
• 6 = normal
• 5 = localized to pain
• 4 = withdraws to pain
• 3 = decorticate posture
• 2 = decerebrate posture
• 1 = none
The score in each section is added for a cumulative score of 3–15:
• GCS 3–8: severely depressed consciousness
• GCS 9–12: moderately depressed consciousness
• GCS 13–15: normal to mildly depressed consciousness

Disability

Once airway, breathing, and circulation are addressed in the primary survey, the next priority is to assess disability. The primary focus is on rapidly determining a patient's mental status and neurologic function via physical exam.

The Glascow Coma Scale (GCS) is a rapid and reliable way to quantify a patient's level of consciousness (Table 1.3) [15]. The GCS score allows for quick communication among clinicians about a patient's current mental status and can be important for decision-making.

The neurologic assessment also includes an examination of the cranial nerves, pupils, and sensory and motor function. If there is an obvious extremity deformity or wound, the clinician should document gross neurologic and vascular

function distal to the injury prior to any manipulation, wound exploration, or tourniquet application. For severely deformed limbs with obvious underlying fractures, a gross reduction should be performed to approximate more normal alignment (if tolerated by the patient), which will often result in improved perfusion of the limb.

One serious disorder that will be diagnosed and treated during the disability segment of the primary survey is intracranial hypertension. Signs of intracranial hypertension include an abnormal GCS, a unilaterally blown pupil, and Cushing's triad (bradycardia, hypertension, and abnormal respiratory variation) in a patient with a suspected head injury. Mild hyperventilation is a temporary way to control elevated intracranial pressure (ICP), with a goal pCO_2 of 30–35 mmHg. Deep sedation is also helpful, but may obscure the clinician's ability to assess the patient. All patients suspected of having an elevated ICP should be considered for hyperosmolar therapy until neurosurgical assessment and intervention can be performed. Hyperosmolar therapy consists of either a bolus of 23.4 % hypertonic saline (0.5 mL/kg) or the administration of mannitol (1 g/kg). Note that mannitol can precipitate hypotension, so it should be administered carefully, and its use may necessitate subsequent resuscitation with isotonic crystalloid.

Exposure/Environment

Exposure and environment are the final components of the primary survey. While lowest in priority, they are still vital to the successful management of the trauma patient. The patient should be completely exposed (all clothing removed) so that injuries can be fully assessed. Decontamination may also be needed, depending on the nature of the trauma. Protection from hypothermia and continuous temperature monitoring are essential. Warm resuscitation fluids should be given. The patient should be covered with warm blankets or a forced-air warming device (e.g. Bair Hugger), and the temperature in the resuscitation area should be warm. If the patient is wet, he or she should be dried immediately. Critically injured patients with hypothermia may require more aggressive methods of rewarming, such as warm lavage of body cavities (e.g., pleural, peritoneal, and bladder lavage), warming/cooling catheters, and/or extracorporeal blood warming (e.g. veno-venous cardiopulmonary bypass) [16].

Reevaluation

Frequent reevaluation should be the rule for trauma patients, even after all five components of the primary survey have been addressed. For some patients the primary survey will need to be completed multiple times. For the critically ill, it is often helpful to repeat the primary survey every time the patient is transferred to a new area of care (e.g., from the emergency department to the intensive care unit). The physiology of the trauma patient is dynamic as injuries may evolve during the assessment. If at any point, the patient begins to respond in a way not consistent with the initial primary survey, then the primary survey should be repeated quickly to assess if a new, immediately life-threatening situation has arisen.

Adjuncts to the Primary Survey

Monitoring

While not explicitly a part of the primary survey, monitors should be placed on the patient to facilitate assessment as soon as possible. Continuous monitoring of cardiac rhythm is helpful to quickly detect changes in heart rate as well as arrhythmias. Continuous O_2 saturation and continuous end-tidal CO_2 monitoring are essential to remain vigilant about changes in the respiratory status of a patient. Automatic noninvasive blood pressure measurements can alert the trauma team to trends or sudden changes in blood pressure. In some patients with hemodynamic variability, a more invasive monitor

will be needed such as an arterial line to monitor blood pressure continuously. Monitoring central venous pressure or pulmonary artery pressure can be a useful adjunct to managing complex trauma patients, especially those with known cardiac disease or suspected cardiac injury.

Imaging

In most trauma centers, rapid portable X-rays are available in the emergency department. X-rays are only adjuncts to the primary survey, but can be very helpful in identifying problems that may impact the primary survey. Most commonly, a portable chest radiograph is performed in the resuscitation area of the emergency department. Chest radiography can confirm the position of an advanced airway, as well as diagnose pneumothorax, hemothorax, pulmonary contusion, aspiration, and broken ribs, all common diagnoses which are important to identify early. Blunt trauma patients often benefit from a portable pelvic plain film. The presence of a pelvic fracture can explain occult blood loss in a hemodynamically unstable patient. Patients with penetrating trauma, especially from a projectile, also can benefit from a plain film to localize the presence of any foreign bodies and guide interventions.

Ultrasound has an important role as an adjunct to the primary survey in localizing occult hemorrhage. In particular, the Focused Assessment Sonography in Trauma (FAST) exam is used to rapidly and reliably identify free fluid in the peritoneum or fluid around the heart. The FAST Exam is a bedside sonographic exam that utilizes four views or "windows." Three abdominal views examine the perihepatic space, the perisplenic space, and the pelvis. The fourth view looks for fluid in the pericardium. For example, in a hemodynamically unstable patient, the FAST exam can quickly identify intra-abdominal hemorrhage as the likely source of bleeding and alert the trauma team that the patient should be transferred to the operating room expeditiously for laparotomy and hemorrhage control [17]. Likewise, a positive pericardial view (especially in a patient with penetrating trauma to the chest) can alert the surgeon that exploration of the chest may be needed [18]. The FAST exam has become the modality of choice to assess the unstable trauma patient and has supplanted diagnostic peritoneal lavage (DPL) as a noninvasive way to look for intra-abdominal hemorrhage [19]. DPL should be used when ultrasound is unavailable, the FAST is equivocal, or a patient has unexplained profound hypotension despite a negative FAST exam.

Computed tomography (CT) is a useful tool in the management of trauma patients, due to the fact that it is more sensitive and specific for most anatomic injury patterns than plain films or ultrasound. In particular, for head injury, CT scan is the primary modality used to guide intervention. For the unstable patient, however, a CT scan can be unsafe due to the time required for the scan, as well as the relatively uncontrolled environment that occurs during transportation and within the scanner. The barriers to obtaining a CT scan expediently and safely vary greatly between institutions, but the general rule is that only patients with a stable airway, good oxygenation and ventilation (mechanical or spontaneous), and hemodynamic stability should receive a CT scan. If a patient becomes unstable in the CT scanner, the team should reevaluate according to the primary survey paradigm and consider abandoning the study if the patient cannot be stabilized.

Laboratory

While laboratory studies are not considered to be an integral component of the primary survey, they can often serve as useful adjuncts. During resuscitation, an arterial blood gas measurement is performed to assess oxygenation, ventilation, and pH. Often, rapid arterial blood gas results are used for close monitoring and to help establish an end point for resuscitation. Venous blood samples are usually obtained during the primary survey, while IV access is being obtained. Importantly, a "type and screen" must be sent

to establish blood type and screen for antibodies to red blood cells. A complete blood count and coagulation studies are especially important in patients who are anemic or anticoagulated. A pregnancy test should be performed in any woman of child-bearing age. Toxicology studies are also helpful in any patient with altered mental status. In patients with abdominal or pelvic trauma, a urinalysis should be checked for hematuria. Blood sugar and other chemistries are also important, especially in patients with unexplained altered mental status.

Tubes

A clinician must be particularly cautious when placing a urinary catheter in a patient with a pelvic fracture (especially in a male patient) or penetrating trauma near the pelvis and perineum. This is particularly true when there is concomitant gross hematuria or blood at the urethral meatus.

Gastric tubes are helpful adjuncts in patients who are mechanically ventilated, to decompress the stomach and decrease the risk of aspiration of stomach contents. After confirmation of correct positioning of the gastric tube, medication and later enteral nutrition can be delivered. In a patient with a complex facial or basilar skull fracture, a nasogastric tube could inadvertently be passed through the fracture site and into the intracranial space. An orogastric tube is a safer alternative until the presence of these types of injuries can be excluded.

Secondary Survey

Next, attention is turned to the secondary survey, whose purpose is to characterize injuries and uncover any occult injuries that did not require immediate attention during the primary survey. In practice, the secondary survey often begins while the primary survey is still being completed. The primary survey, however, should never be interrupted by the secondary survey. Additionally, at any time, a change in the status of the patient may necessitate a return to the primary survey.

History

In the conscious individual, a history can be obtained directly; however, in a severely incapacitated trauma patient, this information must be acquired from pre-hospital personnel, witnesses, and friends or family members. Due to the time-sensitive nature of treatment, a concise history is gathered utilizing the mnemonic AMPLE:

Allergies
Medications
Past medical problems and surgery
Last Meal
Events related to the Injury

In some cases, this information will be obtained from items in the patient's belongings such as medical bracelets, medication bottles, or medical/insurance wallet cards. Pre-hospital personnel may have spoken to witnesses of the traumatic event and can give information about the patient's status in the field and treatment delivered. Taking a trauma history is skill that improves with experience. As a provider sees certain patterns of injury repeatedly, history taking will become tailored for those circumstances. For example, inquiries should be made as to tetanus status in patients with lacerations or abrasions, helmet use in motorcyclists, and weapons and ballistics in patients with gunshot wounds.

Physical Exam

The secondary survey should include a careful "head to toe" physical exam. Remember that the primary survey is focused on an assessment for immediately life-threatening problems, and the secondary survey is used to uncover occult injuries that might have substantial morbidity and mortality if missed. The physical exam will guide the diagnostic and therapeutic approach to be undertaken during the critical hours after the initial resuscitation and assessment, therefore ensuring that the problems with greatest priority are addressed most expeditiously.

Neurologic assessment in the primary survey focuses on the level of consciousness (Glasgow Coma Score and gross neurologic function). The secondary survey goes into greater detail. For instance, in a conscious patient with a GCS of 15, it may be important to assess the level of orientation or confusion. More subtle deficits might be found with a mini-mental exam, for example, when attempting to determine if a patient can safely be discharged after a concussion. Other parts of the neurologic assessment that occur during the secondary survey include cranial nerve assessment, rectal tone, reflexes, and coordination. In addition, obvious injuries should elicit a careful neurologic assessment. For instance, cranial nerve VII will be checked carefully in a patient with a deep facial laceration. Likewise, a complete neurologic and functional examination of the hand should be performed in a patient with a wrist deformity or fracture.

The head, scalp, and face require careful attention on the secondary survey. Ongoing blood loss from a scalp laceration can be hidden in long hair. The skull should be palpated for discontinuities, "step-offs", or other signs of fracture. Rhinorrhea, hemotympanum, raccoon's eyes (bruising around the eyes), or Battle's sign (blood over the mastoid process) are suggestive of basilar skull fracture and should be noted during the secondary survey. Facial lacerations and fractures are common in trauma, can be quite disfiguring, and often impact long-term function. An unstable midfacial area or maxilla are physical exam signs that may help diagnose a LeFort fracture prior to imaging studies. The presence of malocclusion or difficulties in mouth opening should be noted and are especially relevant in cases in which a patient later needs an advanced airway.

The neck receives special attention in trauma patients. Patients usually arrive in the emergency room with a rigid cervical collar in place. For the neck exam, this collar should be removed while the spine is held in an immobilized position. In particular, tracheal deviation, neck hematomas, bruits, subcutaneous emphysema, lacerations, and gunshot wounds should be considered carefully. If the cervical spine collar is interfering with the ability to care for obvious neck injuries, it should not be used, and an individual should hold the spine in alignment until these injuries are stabilized and the collar can be replaced.

The chest, abdominal, back, and genital exams should be performed more carefully during the secondary survey. Chest wall point tenderness, rales, and wheezing may be found. Abdominal tenderness, especially in patients with penetrating trauma, is an indication for urgent surgical exploration. The back exam is performed with the patient's spine in stable alignment using the "log roll" maneuver. The clinician should look for any additional penetrating wounds to the back or axillae. In men, the genitalia are examined to look for gross blood at the urethral meatus, priapism, or degloving injuries. In women, blood at the vaginal introitus and any lacerations to the perineum should be noted.

Extremities should be inspected for deformity and color and palpated for point tenderness, instability, or crepitus. All limbs should be moved throughout their range of motion to assess for mobility or laxity in the joints. A peripheral vascular and neurologic evaluation of the extremity should be carefully performed when an injury is found.

Disposition from the Trauma Resuscitation Area

The amount of time a patient initially spends in the emergency department resuscitation area can vary greatly. Some patients will be whisked away to the operating room for treatment of life-threatening injuries after mere seconds. Others may require more than an hour of resuscitation, reevaluation, and intervention. The care of every patient begins with the primary survey. If life-threatening injuries are encountered that can only be managed elsewhere, such as the operating room or angiography suite, then the primary survey will continue until that life-threatening problem is addressed. The primary survey is not

complete until the patient is stabilized. Most trauma patients will receive a complete primary survey and secondary survey before being transferred from the resuscitation area. Commonly, patients will be transferred to one of the following destinations: radiology (CT scan, MRI), intensive care unit, inpatient unit, procedure/treatment room (operating room, angiography, endoscopy), or to a less acute section of the emergency department for observation and possible discharge to home. It is important that patients are monitored appropriately and that the new care team receives adequate information as part of transfer. Oftentimes, a nurse, respiratory therapist, physician, and transport personnel will accompany the patient to the next level of care (e.g., the ICU). Vigilance is key. A suicidal patient may have an unremarkable primary and secondary survey, but will need careful monitoring for elopement or self-injury. Evolution of a trauma patient's condition can be quick and occur in the hours after the patient's initial assessment. For example, a patient with a delayed hemorrhage will deteriorate over the next several hours, even in the presence of initially normal vital signs. The clinician should have a low threshold to return to the primary survey if anything unexpected occurs. Good care of the trauma patient means going "back to the ABCs" as many times as it takes until the patient is truly stable.

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