Initial Management of the Trauma Patient

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Learning Aims

- Sequence of trauma patient assessment
- Primary survey: assessment of the airway, breathing, and circulation
- Secondary survey: abbreviated patient history, objective assessment from head to toe
- Identification and management of common trauma injuries based on body systems, including recognition of opioid overdose

The initial assessment and management of a patient's injuries must be completed in an accurate and systematic manner to quickly establish the extent of any injury to vital life-support systems. Nearly 25–33% of deaths caused by injury can be prevented when an organized and systematic approach is used [1].

Significant data exist to suggest that death from trauma has a trimodal distribution [2]. The first peak on a linear distribution of deaths is within seconds or minutes of the injury. Invariably these deaths are due to lacerations of the brain, brainstem, upper spinal cord, heart, aorta, or other large vessels. Few of these patients can be saved, although in areas with rapid transport and some fortunate circumstances, a few of these deaths have been avoided. The second death peak occurs within the first few hours after injury. The period following injury has been called the "golden hour" because these patients may be saved with rapid assessment and management of their injuries. Death is usually due to central nervous system (CNS) injury or hemorrhage. Recent analysis of trauma system efficacy suggests that trauma deaths could be reduced by at least 10% through organized trauma systems. These patients, whose numbers are significant, benefit most from regionalized trauma care [3]. The third death peak occurs days or weeks after the injury and is usually due to sepsis, multiple organ failure, or pulmonary embolism [4].

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Patients are assessed, and treatment priorities are established following an initial evaluation of the patients' injuries and the stability of the vital signs. In any emergency involving a critical injury, logical and sequential treatment priorities must be established on the basis of overall patient assessment. Injuries can be divided into three general categories: severe, urgent, and nonurgent [2]. Severe injuries are immediately life-threatening and interfere with vital physiologic functions; examples are compromised airway, inadequate breathing, hemorrhage, and circulatory system damage or shock. These injuries constitute approximately 5% of patient injuries but represent over 50% of injuries associated with all trauma deaths. Urgent injuries make up approximately 10–15% of all injuries and offer no immediate threat to life. These patients may have injuries to the abdomen, orofacial structures, chest, or extremities that require surgical intervention or repair, but their vital signs are stable. Nonurgent injuries account for approximately 80% of all injuries and are not immediately life-threatening. This group of patients eventually requires surgical or medical management, although the exact nature of the injury may not become apparent until after significant evaluation and observation. Laboratory studies, additional physical findings, radiographic examinations, and observations for several days or weeks may be required [5]. The goal of initial emergency care is to recognize life-threatening injuries and to provide lifesaving and support measures until definitive care can be initiated.

16.1 Introduction

Assessment and management of a patient's injuries must be completed in an efficient and systematic approach to accurately determine the extent of injury and implement proper care as to minimize lasting damage from the injury. The systematic approaches to patient assessment are based on standardized scales such as the Glasgow Coma Scale, Trauma Score, and many other possibilities. The primary survey of a patient addresses the patient's airway status, breathing, and circulation (ABCs), as damage to any of these three systems requires immediate implementation in order to stabilize the patient's vitals. After the primary survey is complete and a patient's vitals are stable, a secondary survey can proceed. The secondary survey functions on a system-by-system basis and often proceeds from the head and neck downward so as to avoid missing secondary injuries. An abbreviated history should be obtained to have a complete set of information with which to evaluate the patient.

Death from trauma primarily occurs in three phases: within seconds to minutes of injury, a few hours after injury, and days to weeks after injury. It is the latter two phases where implementation of efficient and systematic practices can have the greatest impact of reducing possible death. There are three general categorizations of injuries: severe, urgent, and nonurgent [2]. Severe injuries are those that compromise vital physiologic functions and detected in the primary survey of the patient and requiring immediate lifesaving intervention. Severe injuries represent 5% of injuries but constitute 50% of the deaths from injury. Urgent injuries, which constitute 10–15% of injuries, do not pose an immediate threat to life but often require surgical intervention or repair. Nonurgent injuries are also not an immediate threat to life but may require intervention after thorough assessment and observation. The goal of initial emergency care is to recognize life-threatening injuries and to provide lifesaving and support measures until definitive care can be established.

16.2 Assessment of the Severity of Injury

Importance

- Use of efficient, systematic, and standardized scales to assess a trauma patient can reduce trauma mortality.
- Glasgow Coma Scale, quantifying the severity of head trauma based off motor, verbal, and eye opening response.
- Trauma Score and Revised Score, assess injury to vital systems.
- Injury Severity Score, developed for patients with multiple traumatic injuries.

The primary goal of triage is to prioritize victims according to the severity and urgency of their injuries and the availability of the required care. With regional trauma centers in modern trauma systems, the goal of triage is to rapidly and accurately identify patients with life-threatening injuries and to manage these patients with the available resources to achieve the greatest possible outcome while at the same time avoiding unnecessary immediate transport of less severely injured patients (◘ Fig. 16.1) [6–8]. Over the past three decades, many scales and scoring systems have been developed as tools to predict outcomes based on several criteria.

16.2.1 Glasgow Coma Scale

The Glasgow Coma Scale (GCS) was developed in 1974 by Teasdale and Jennet [9]. It was the first attempt to quantify the severity of head injury. The three variables included were best motor response, best verbal response, and eye opening (◘ Table 16.1). Best motor response is a reflection of the level of CNS function, best verbal response shows the CNS's ability to integrate information, and eye opening is a function of brainstem activity. Scores range from 3 to 15, with a higher number representing an increased degree of consciousness. The use of the letter *T* designates that the patient was intubated at the time of the examination.

In a prospective multicenter study, patients with a head injury who had an admission GCS of 9 or less correlated with higher mortality rates, regardless of center volume, mechanism of injury, or treatment [10]; therefore, this scale can be used to predict outcomes. The GCS has weaknesses in that it does not take into account focal or lateralizing signs, diffuse metabolic processes, or intoxication.

16.2.2 Trauma Score and Revised Trauma Score

The Trauma Score was developed by Champion and colleagues to quickly assess the extent of injury to vital systems and the severity of the injury to provide proper triage and treatment of the patient [11]. It was later modified by Champion and colleagues to become the Revised Trauma Score in 1989 [12].

The Trauma Score provided a means of characterizing the physiologic status of injured patients' cardiovascular, respiratory, and neurologic systems. The Trauma Score incorporated five variables: GCS, respiratory rate, respiratory expansion, systolic blood pressure, and capillary refill. The Revised Trauma Score omitted respiratory expansion and capillary refill owing to difficulty assessing these elements in the field and the wide margin for interpretation.

With the original trauma score, the total points added to give a trauma score of 1–15, the higher the score, the better the prognosis. Thus, an injured patient who exhibits eye opening to painful stimulus (score 2), a verbal response that is incomprehensible (score 2), and withdrawal from a painful stimulus (score 4) would have a GCS of 8 points and would contribute 3 points to the trauma score.

The Revised Trauma Score has a coded value for each of the three variables (◘ Table 16.2). A value of 0–4 is assigned for each variable to give a total range of 0–12, with lower scores representing an increasing severity of injury. Trauma scores of around 8 indicate an approximate 33% probability for mortality (◘ Table 16.3) [13, 14]. In 1989, Champion and colleagues performed the Major Trauma Outcome Study, consisting of an analysis of 33,308 trauma patients whose cases were submitted by 89 hospitals across the United States and Canada, with survival probabilities associated with admission trauma scores determined for 25,327 patients. They concluded that patients likely to benefit from prompt diagnosis and definitive care at level I trauma centers are those with an original trauma score of 12 or less [12].

16.2.3 Injury Severity Score

The Injury Severity Score was developed to deal with multiple traumatic injuries. It compares death rates from blunt trauma using data that rate the severity of injury in each of the three most severely injured organ systems. Each injury is evaluated and categorized according to the injured organ system (respiratory, CNS, cardiovascular, abdominal, extremities, and skin) and graded according to the severity of the injury: 1 is minor; 2

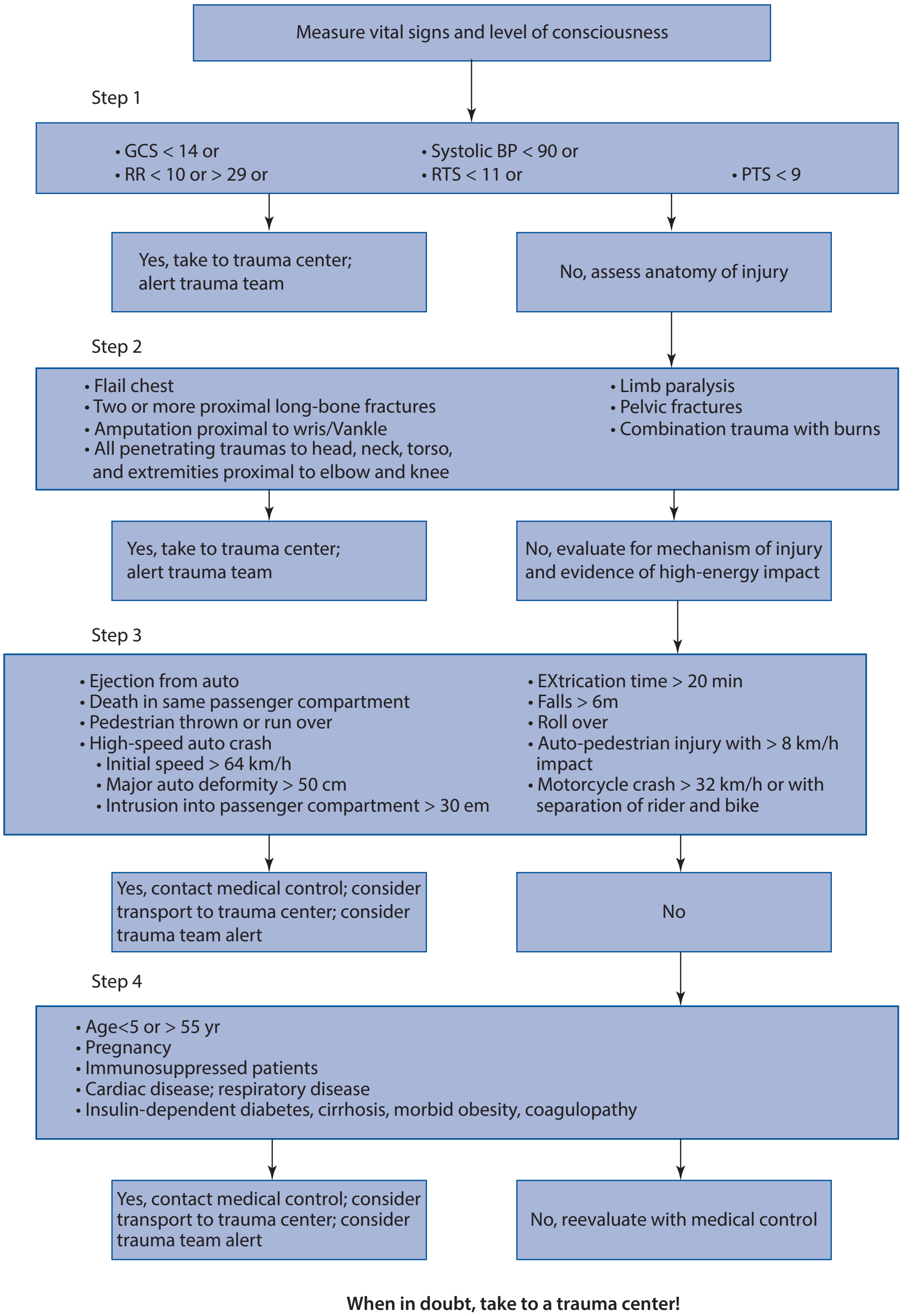

Fig. 16.1 Triage decision scheme. BP blood pressure, GCS Glasgow Coma Scale, PTS Pediatric Trauma Score, RR respiratory rate, RTS Revised Trauma Score. (Adapted from the American College of Surgeons Committee on Trauma [8])

moderate; 3 severe non-life-threatening; 4 life-threatening, survival probable; 5 survival not probable; and 6 fatal cardiovascular, CNS, or burn injuries. The three highest scores for organ systems are then squared and added; the highest injury severity score possible is 108 ($6^2 + 6^2 + 6^2$). Mortality rates have been found to increase with greater severity of injury and age (Table 16.4) [15].

In addition to the field scales that measure abnormal physiologic signs for assessment of injury for triage decisions, mechanism-of-injury factors and anatomic factors are also important considerations. Mechanism-

Table 16.1 Glasgow Coma Scale Glasgow Coma Scale

Action	Score
Eye opening	
Spontaneously	4
To speech	3
To pain	2
None	1
Motor response	
Obeys	6
Localizes pain	5
Withdraws from pain	4
Flexion to pain	3
Extension to pain	2
None	1
Verbal response	
Oriented	5
Confused	4
Inappropriate	3
Incomprehensible	2
None	1

Adapted from Teasdale and Jennett [9]
Patient's score determines category of neurologic impairment: 15 normal, 13 or 14 mild injury, 9–12 moderate injury, 3–8 severe injury

Table 16.2 Revised Trauma Score variables

Glasgow Coma Scale	Systolic blood pressure (mm Hg)	Respiratory rate	Coded value
13–15	>89	10–29	4
9–12	76–89	>29	3
6–8	50–75	6–9	2
4 or 5	1–49	1–5	1
3	0	0	0

Adapted from Champion et al. [12]

of-injury factors can provide insight to a possible significant injury that has not yet resulted in significant changes in vital signs. Although data evaluation is important, it is important to remember that clinical evaluation always trumps mechanism-of-injury data when the vital signs are stable. Those such factors that have a high correlation with life-threatening injuries include the following [16]:

- Evidence of a collision involving high-energy dissipation or rapid deceleration
- A fall of 6 m or more
- Evidence that the patient was in a dangerous environment when injured (e.g., a burning building or icy water)
- An automobile accident in which it takes >20 min to remove the patient, there is significant damage to the passenger compartment, rearward displacement of the front axle has occurred, the patient is ejected from the vehicle, a rollover occurs, or other passengers have died

Anatomic factors that correlate with mortality include penetrating trauma to the head, neck, torso, groin, or thigh; flail chest; major burns; amputations; two or more proximal long-bone fractures; and paralysis. Concurrent disease or factors such as age of <5 years or >55 years and known cardiac or respiratory disease may sharply worsen a patient's prognosis, even in the presence of only a moderately severe injury [17].

Table 16.3 Predicting mortality using the Revised Trauma Score

Trauma score	Mortality rate (%)
12	<1
10	12
8	33
6	37
4	66
2	70
0	>99

Adapted from Senkowski and McKenney [14]

Table 16.4 Mortality rates for various injury severity scores by age groups

		Mortality rates for scores (%)				
Age (year)	*n*	15	25	35	45	55
0–49	1540	3	8	32	61	89
50–69	316	5	21	56	68	100
70+	109	16	45	82	100	100

Adapted from Powers [15]

The American College of Surgeons Committee on Trauma Subcommittee on Advanced Trauma Life Support has developed a schematic orderly assessment of injured patients. The Advanced Trauma Life Support (ATLS) system consists of rapid primary evaluation, resuscitation of vital functions, a detailed secondary assessment, and, finally, the initiation of definitive care (see ◘ Fig. 16.1) [7].

16.2.4 Other Scoring Systems

Many other scoring systems and tools have been created in attempts to accurately aid triage and to predict outcomes, including the Pediatric Trauma Score [18], the Trauma and Injury Severity Score [19], and A Severity Characteristic of Trauma Score [20]; recently scales using the ninth edition of International Classification of Diseases nomenclature have been implemented including an International Classification of Disease-Based Injury Severity Score [21].

16.3 Primary Survey: ABCs

Importance

- Primary survey is of the airway, breathing, and circulation (ABCs) of the patient.
- Airway: highest priority; establish and maintain the patient's airway.
- Breathing: assess breathing of patient; chest movement does not indicate adequate ventilation.
- Circulation: confirm that all systems are being perfused; most common cause of shock is hypovolemia due to hemorrhage.
- Neurologic examination: establishes the patient's level of consciousness.

An algorithm for the initial systemic evaluation and stabilization of the multiply injured patient is presented in ◘ Fig. 16.2. During the primary survey, life-threatening conditions are identified and reversed quickly. This period calls for quick and efficient evaluation of the patient's injuries and almost-simultaneous lifesaving intervention. The primary survey progresses in a logical manner based on the ABCs: *a*irway maintenance with cervical spine control, *b*reathing and adequate ventilation, and *c*irculation with control of hemorrhage. Letters D and E have also been added: a brief neurologic examination to establish *d*egree of consciousness and *e*xposure of the patient via complete undressing to avoid injuries being missed because they are camouflaged by clothing. With exposure of the patient, temperature preservation of the patient is extremely important.

16.3.1 Airway Maintenance with Cervical Spine Control

The highest priority in the initial assessment of the trauma patient is the establishment and maintenance of a patent airway. In the trauma patient, upper airway obstruction may be due to bleeding from oral or facial structures, aspiration of foreign materials, facial fractures, airway structure trauma, or regurgitation of stomach contents. Commonly, the upper airway is obstructed by the position of the tongue, especially in the unconscious patient (◘ Fig. 16.3). Initially a chin-lift or jaw-thrust procedure may position the tongue and open the airway. The chin-lift procedure is performed by placing the thumb over the incisal edges of the mandibular anterior teeth and wrapping the fingers tightly around the symphysis or the mandible. The chin is then lifted gently anteriorly and the mouth opened, if possible. This method should not hyperextend the neck [8]. The other hand can be used to assist with access to the oral cavity, using the fingers in a sweeping motion to remove such things as debris, vomitus, blood, and dentures that may be responsible for the obstruction. A tonsillar suction tip is helpful to remove accumulations from the pharynx. Patients with facial injuries who may have basilar skull fractures or fractures of the cribriform plate may, with the routine use of a soft suction catheter or nasogastric tube, be compromised as these tubes may inadvertently be passed into the contents of the cranial vault during attempts at a pharyngeal suction.

The jaw-thrust procedure requires the placement of both hands along the ascending ramus of the mandible at the mandibular angle. The fingers are placed behind the inferior border of the angle, and the thumbs are placed over the teeth or chin. The mandible is then gently pulled forward with the fingers at the angle and rotated inferiorly with pressure from the thumbs. The elbows may be placed on the surface alongside the patient to assist with stability. The jaw-thrust procedure is the safest method of jaw manipulation in a patient with a suspected cervical injury. The jaw-thrust procedure does require two hands, and assistance must be available to clear the debris and other obstructions. After the jaw is opened, it may be possible to place a bite lock or large suction device to wedge the teeth open. An oral or nasal airway should be placed to elevate the base of the tongue and to maintain the patent airway.

With any patient sustaining injuries above the clavicle or with decreased levels of consciousness, one should assume there may be a cervical spine injury and avoid hyperextension or hyperflexion of the patient's neck during attempts to establish an airway. Excessive movement of the cervical spine can turn a fracture without neurologic damage into a fracture that causes paralysis.

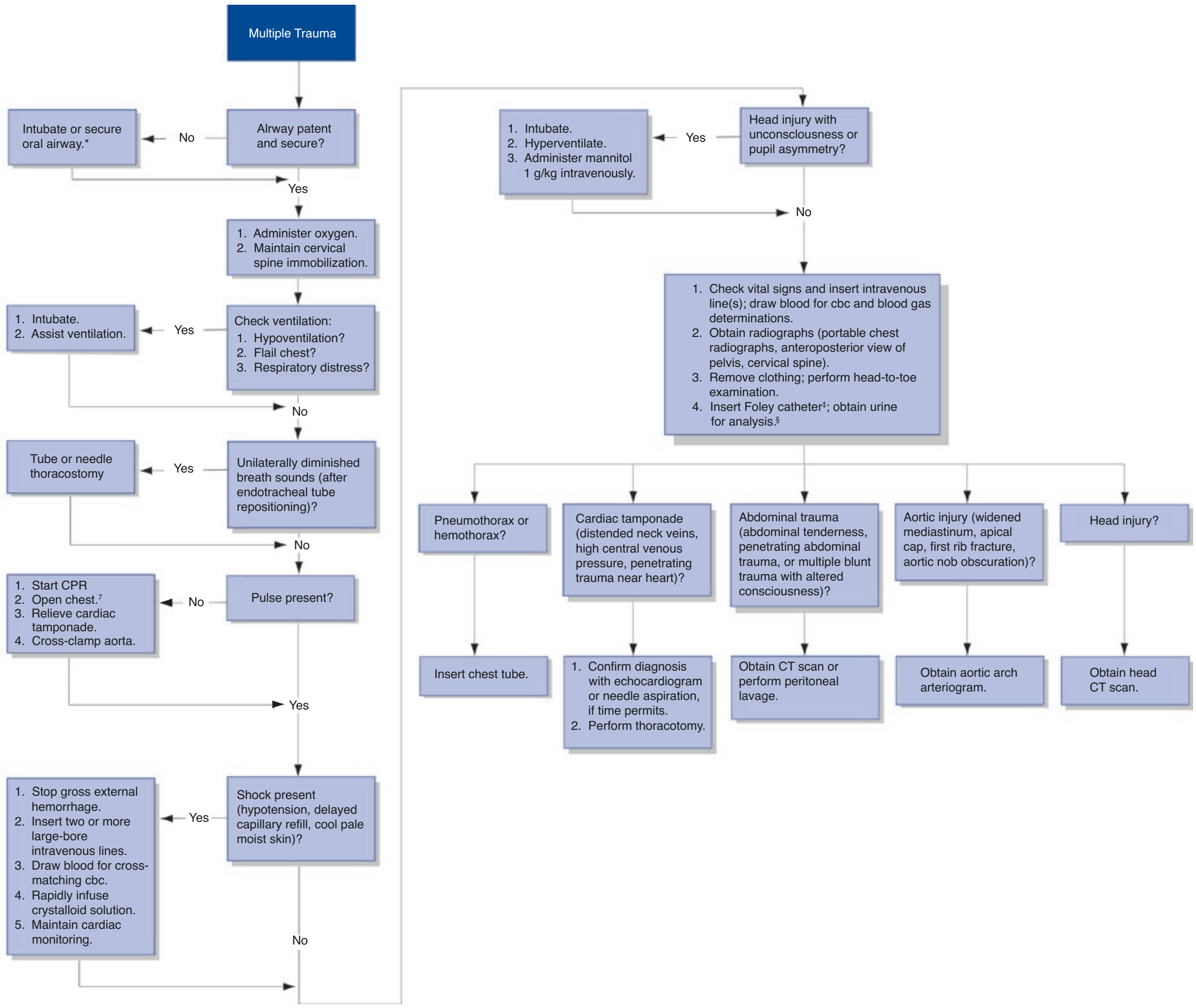

Fig. 16.2 Multiple trauma algorithm. cbc complete blood count, CT computed tomography. *Maintain cervical spine precautions. Nasotracheal intubation (preferred) or orotracheal intubation with axial head traction. †Unlikely to be of benefit for blunt trauma with asystole. Perform only if experienced with the procedure and if there is adequate surgical support. ‡If not contraindicated (i.e., high-riding prostate, meatal blood, scrotal hematoma). §If not contraindicated (i.e., midface or cribriform plate fracture). (Adapted from Trunkey [76])

Maintenance of the cervical spine in the neutral position is best achieved with the use of a backboard, bindings, and purpose-built head immobilizers. The use of soft or semirigid collars allows, at best, only 50% stabilization of movement [22]. Cervical spine injury should be assumed present and protected against until the patient can be stabilized and cervical injury can be ruled out during the secondary survey. Oral airway devices are usually preferred with patients with decreased levels of consciousness.

16.3.2 Breathing

With establishment of an adequate airway, the pulmonary status must be evaluated. If the patient is breathing spontaneously—confirmed by feeling and listening for air movement at the nostrils and mouth— supplemental oxygen may be delivered by face mask. The exchange of air does not guarantee adequate ventilation. The chest wall of a patient with a pneumothorax, flail chest, or hemothorax may move but not ventilate effectively.

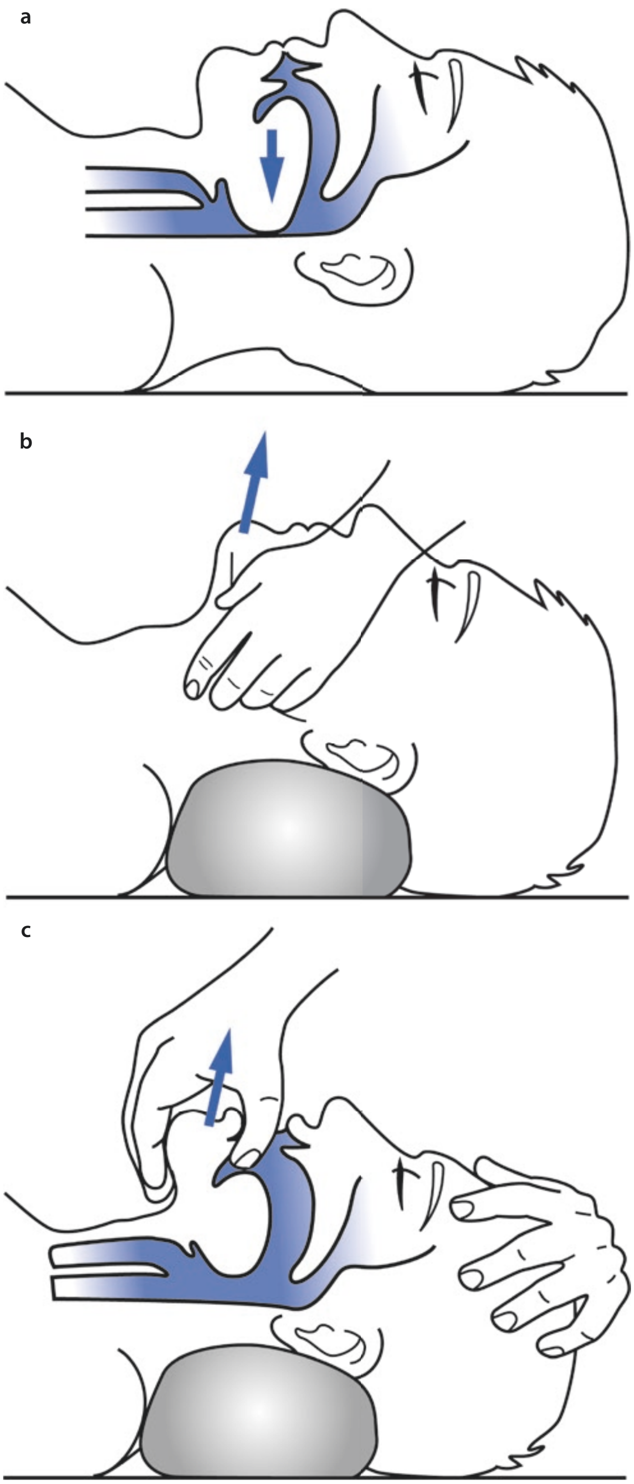

Fig. 16.3 **a** Commonly in the unconscious patient, the tongue drops posteriorly to occlude the airway. This may be especially true in the patient with mandibular fractures because the tongue loses support. A patient with a suspected maxillofacial or head trauma must have the head stabilized at all times to prevent hyperflexion of an injured cervical spine until the possibility of injury has been ruled out. **b** With the cervical spine stabilized, a jaw-thrust may be used. **c** A chin-lift procedure also may be helpful to open the airway. (Adapted from Powers [15])

Also, shallow breaths with minimal tidal volumes do not ventilate the lungs effectively. Very slow or rapid rates of respiration usually suggest poor ventilation. The patient's status should be reevaluated constantly. If signs of adequate ventilation deteriorate, a secure airway should be placed (ideally an endotracheal tube), and assisted ventilation should be started. If the patient is not breathing after establishment of an airway, artificial ventilation should be provided with a bag-valve mask or a bag attached to an endotracheal tube. The patient who requires assisted positive pressure ventilation from an Ambu bag or ventilator must be carefully monitored if the chest status has not been completely evaluated. Changes in intrathoracic pressure may convert a simple pneumothorax into a tension pneumothorax. The chest should be exposed and inspected for obvious injuries and open wounds. There should be equal expansion of the chest wall without intercostal and supraclavicular muscle retractions during spontaneous respiration. The rate of breathing should be evaluated for tachypnea or other abnormal breathing patterns. Signs of chest injury or impending hypoxia are frequently subtle and include anxiety, an increased rate of breathing, and a change in breathing pattern, frequently toward shallower respirations [7]. The chest wall should also be inspected for bruising, flail chest, and bleeding, and the neck should be evaluated for evidence of tracheal deviation, subcutaneous emphysema, and distended jugular veins. The chest should be palpated for the presence of rib or sternal fractures, subcutaneous emphysema, and wounds. Auscultation of the chest may reveal a lack of breath sounds in an area, suggestive of inadequate ventilation. Distant heart sounds and distended neck veins are suggestive of cardiac tamponade. Arterial oxygen tension (PaO_2) should be maintained between 80 and 100 mm Hg. Aside from airway obstruction, the causes of inadequate ventilation in the trauma victim result from altered chest wall mechanics. Open pneumothorax, flail chest, tension pneumothorax, and massive hemothorax are immediate life-threatening conditions and should be quickly identified and treated.

Open Pneumothorax An open pneumothorax is due to a defect in the chest wall, allowing the air to be moved in and out of the pleural cavity with each respiration (Fig. 16.4). Because of the loss of chest wall integrity, equilibrium develops between intrathoracic pressure and atmospheric pressure. The involved lung collapses on inspiration and slightly expands on expiration, causing air to be sucked in and out of the wound; this is referred to as a sucking chest wound. If the opening in the chest wall is approximately two-thirds of the diameter of the trachea, air will pass through the path of least resistance—the chest wall defect. With the collapse of the involved lung

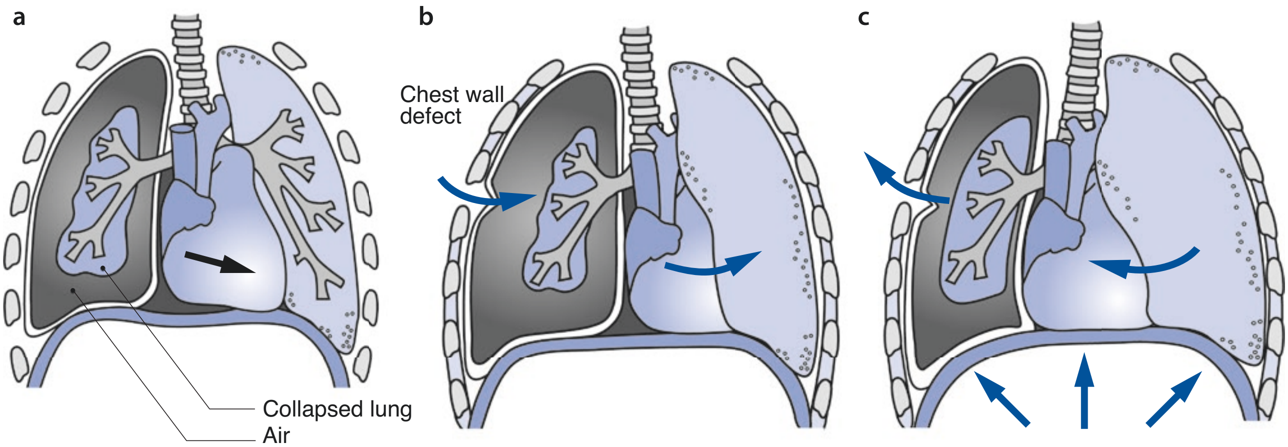

Fig. 16.4 **a** A pneumothorax develops from damage to the chest wall or laceration of the lung pleura, with a resulting loss of negative intrapleural pressure. A pneumothorax may be graded as small (15–60%) or large (>60%). **b** and **c** An open or communicating chest wound occurs when there is an open wound in the chest wall. Air can often be heard moving in and out of the wound during respirations; the condition may be referred to as a sucking chest wound. An open pneumothorax may be converted to a simple pneumothorax with the use of an occlusive dressing over the chest wall wound. Care must be taken not to create a trapdoor effect and cause a tension pneumothorax to develop. (Adapted from Powers [15])

and a loss of negative pleural pressure, the expired air from the normal lung passes to the involved lung instead of out of the trachea, and it returns to the normal lung on inspiration. This eventually results in a large functional dead space in the normal lung and, combined with loss of the involved lung, may develop into a severe ventilation-perfusion problem.

An open pneumothorax should be treated with coverage of the defect with a sterile occlusive dressing that is secured on three sides of the dressing to the chest. The unsecured side of the dressing acts as a one-way valve, allowing air to escape the pleural cavity on expiration. Secure taping of *all* edges of the dressing results in an accumulation of air within the thoracic cavity and a subsequent tension pneumothorax. Occlusive dressings such as petrolatum gauze may be used as a temporary measure during initial examination or over large defects. A chest tube must be placed in a distant site on the affected chest wall to avoid development of a tension pneumothorax, and the wound must eventually be closed in the operating room. If the lung does not expand after closure of the defect or if signs of poor ventilation persist, the patient should be placed on a ventilator with positive end-expiratory pressure (PEEP) to expand the lung. The patient should be carefully monitored and have a chest tube in place to avoid the development of a tension pneumothorax caused by a tear in one of the bronchi or in the lung parenchyma. Signs of a tension pneumothorax in patients on ventilators include increased airway resistance and diminished tidal volume.

A closed pneumothorax may develop from blunt trauma to the chest or a lung laceration, possibly from a fractured rib. Air escapes from the lung into the pleural space. As the pressures equalize, the affected lung collapses. A ventilation-perfusion deficit occurs because the blood circulated to the affected lung is not oxygenated. With a pneumothorax, percussion of the chest shows hyperresonance. Breath sounds are usually distant or absent; however, in the noisy trauma bay during the initial examination of the victim, breath sounds may be difficult to appreciate. Management of the pneumothorax is confirmed and evaluated with upright chest radiographs. An open pneumothorax that has a dressing placed over the chest wound becomes a closed pneumothorax.

Pneumothoraces that are traumatically induced are usually treated with a tube thoracostomy to correct any respiratory compromise. A small pneumothorax may be treated by hospitalization and careful observation if the patient is otherwise healthy, is symptom-free, and does not need general anesthesia or positive pressure ventilation and if the size of the pneumothorax is not increasing as measured on serial 24-h chest radiographs [23, 24]. This is rarely the case with the trauma victim, and a chest tube should be placed immediately in the multiply injured patient with a pneumothorax. Consideration should also be given to placing a chest tube in patients with chest trauma who will be transferred between facilities especially by helicopter or airplane (Fig. 16.5).

A moderate-sized chest tube (32–40F in adults or 26–30F in children) is generally placed either anteriorly in the second intercostal space midclavicular line or in the fifth intercostal space midaxillary line. The midaxillary line is generally preferred for cosmetic reasons, and if the tube is positioned properly superiorly toward the

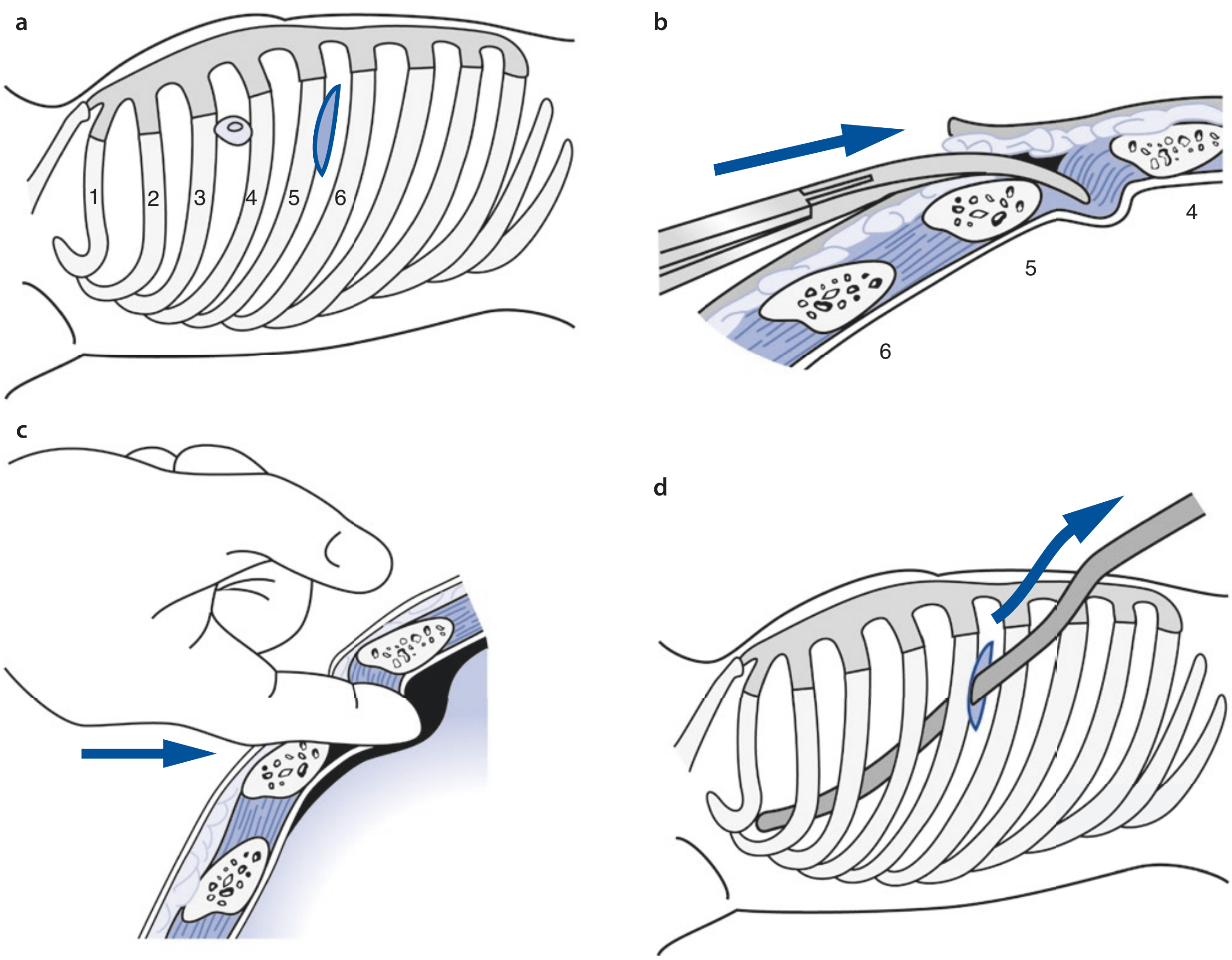

Fig. 16.5 Chest tube placement. The patient should be supine with the arm positioned superiorly to assist with access to the midaxillary line. **a** An incision is made through the skin and subcutaneous tissue along the inferior aspect of the fifth rib. **b** A large Kelly clamp is used, with the tips placed inferiorly, to bluntly dissect over the fifth rib into the intercostal space between the fourth and fifth ribs. **c** A gloved finger should be used to enter the pleural space to avoid possible laceration of structures, within the pleural space, such as the lung, or possible disruption of abdominal contents in case of a ruptured diaphragm. **d** The chest tube is then passed along the finger, superiorly and posteriorly within the pleural cavity. The tube should be secured to the chest with sutures, covered with an occlusive dressing, and then connected to an underwater sealed drainage, which creates suction, following verification of tube position by chest radiographs. (Adapted from Powers M [15])

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apex of the lung, it can effectively remove both fluid and air. In initial trauma management, the placement of the chest tube is usually in the fifth intercostal space.

A skin incision of approximately 3 cm in length is made one intercostal space below the intended placement of the tube. If the tube is to be placed through the fifth intercostal space, an incision is made through the skin along the sixth intercostal space. A gloved finger is used to tunnel transversely through the subcutaneous tissue to the inferior margin of the fifth rib. The intercostal muscles are separated with a large Kelly clamp, and the chest tube is inserted over the superior margin of the fifth rib to avoid the neurovascular bundle traveling on the inferior margin of the fourth rib and advanced superiorly and posteriorly into the pleural cavity. The tube should be secured to the skin with sutures, and an occlusive dressing should be used to cover the defect around the tube. The tube is then connected to an underwater sealed drainage to remove the air or fluid. Upright posteroanterior and lateral chest radiographs should be taken to confirm the position of the chest tube, the position of the last drainage hole on the tube, and the position and amount of air or fluid remaining in the pleural cavity. Daily physical examination and radiographs should be performed to monitor progress of removal of air or fluid. If the tube becomes blocked and significant fluid or air remains, a new chest tube should be placed.

Tension Pneumothorax A tension pneumothorax develops when the injury acts as a one-way valve through the

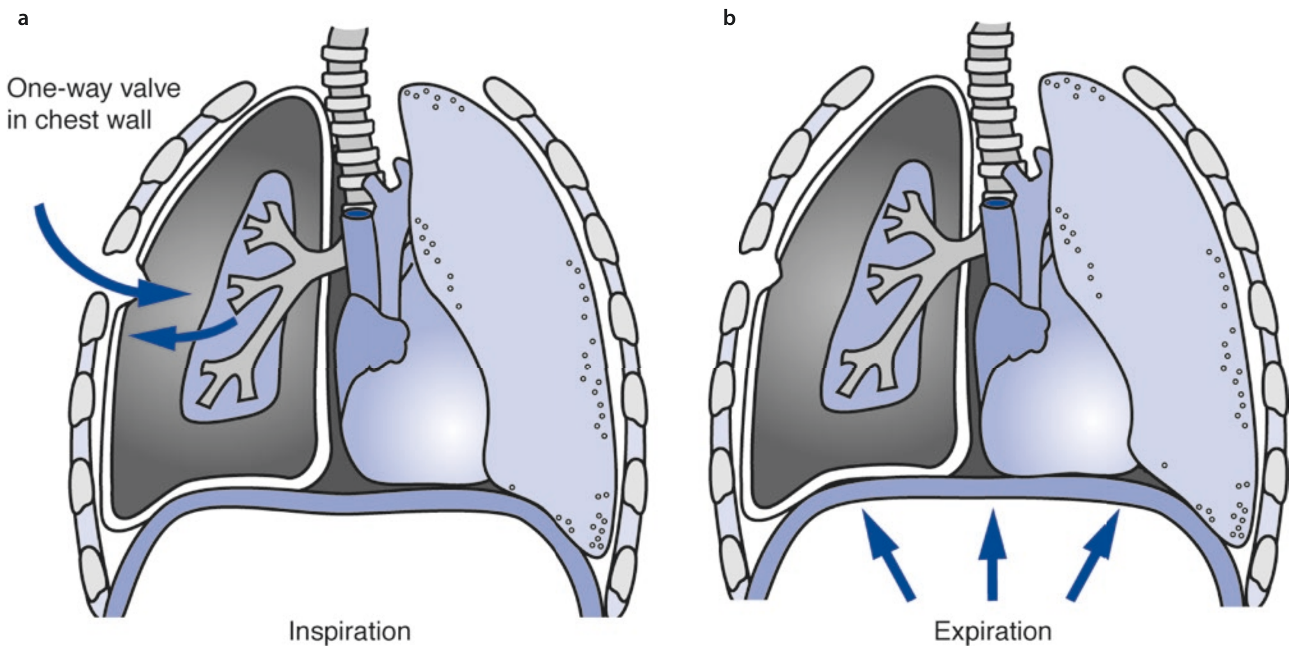

Fig. 16.6 A tension pneumothorax develops as air enters the pleural cavity on inspiration but cannot leave during expiration **a**, resulting in a progressive increase in intrapleural air pressure **b**. The injury in the chest wall or trachea acts like a one-way valve, and the increasing intrapleural pressure results in a shift of the trachea and mediastinal structures away from the injury. The pressure on the vena cava does not allow for an adequate return of blood to the heart, and compression of the opposite lung (added to the injured lung) causes severe ventilatory disturbance. (Adapted from Vukich and Markovchick [77])

chest wall or from the lung into the pleural cavity without equilibration with the outside atmosphere (Fig. 16.6). A dangerous progressive increase of intrapleural pressure develops as air enters the pleural cavity on inspiration but cannot escape on expiration, causing complete collapse of the affected lung. As the pressure increases, the trachea and mediastinum are displaced to the opposite pleural cavity and impinge on the normal lung. The positive intrapleural pressure compresses the vena cava, leading to decreased cardiac output. The compression of the normal lung causes shunting of blood to nonventilated areas and severe ventilatory disturbances. These changes develop into a rapid onset of hypoxia, acidosis, and shock [24].

The most common causes of tension pneumothorax are mechanical ventilation with PEEP, spontaneous pneumothorax in which emphysematous bullae have failed to seal, and blunt chest trauma in which the parenchymal lung injury has failed to seal. Occasionally, traumatic defects in the chest wall may lead to tension pneumothorax [7]. The presence of a pneumothorax should be considered in patients who rapidly become acutely ill; develop severe respiratory distress; and exhibit decreased breath sounds, hyperresonance on one side of the chest, distended neck veins, and deviation of the trachea away from the involved side. If untreated, a tension pneumothorax results quickly in death. If a developing tension pneumothorax is suspected, the positive intrapleural pressure should be released as quickly as possible. The pressure can be released by inserting a large-bore (14–16-gauge) needle anteriorly into the affected hemithorax through the second or third intercostal space in the midclavicular line. This quickly converts the tension pneumothorax to a pneumothorax, which can be treated with placement of a chest tube (Fig. 16.7).

Hemothorax *Hemothorax* is the collection of blood in the pleural cavity. It is commonly the result of penetrating injuries that disrupt the vasculature, but it can result from blunt trauma that tears the vasculature. The initial loss of blood collected in the pleural cavity may come from lung injuries, but because of low pulmonary arterial pressure, the blood loss is usually slowed. Massive hemothorax usually results from injuries to the aortic arch or pulmonary hilum; it may also result from injuries to the internal mammary arteries or intercostal arteries, which are branches of the aorta. A hemothorax may dangerously reduce the vital capacity of the lung and contribute to hypovolemic shock. A hemothorax is usually associated with a pneumothorax, and the subsequent blood loss causes hypotension, a decreased cardiac output, and metabolic acidosis, which, when combined with the ventilatory compromise, results in hypoxia and respiratory acidosis.

A hemothorax should be suspected following penetrating or blunt chest trauma if the patient is in shock

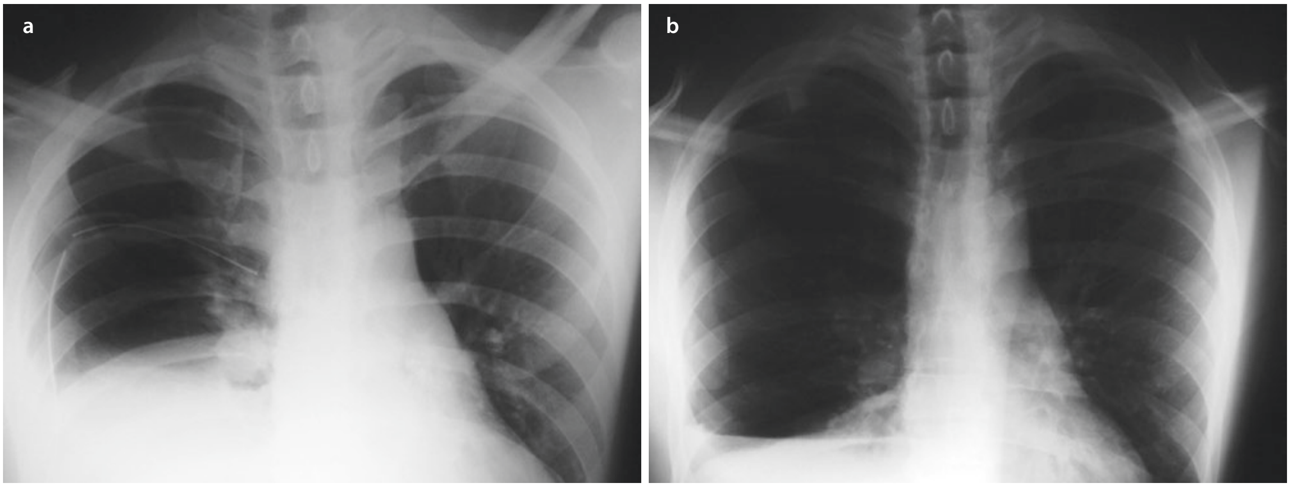

Fig. 16.7 **a** Right pneumothorax. A closed pneumothorax may develop from blunt trauma to the chest or a lung laceration, possibly from a fractured rib. Air from the lung to the pleural space equalizes the pressures, and the lung collapses. A ventilation-perfusion deficit occurs because the blood circulated to the affected lung is not oxygenated. With a pneumothorax, percussion of the chest shows hyperresonance. Breath sounds are usually distant or absent. Management of the pneumothorax is confirmed and evaluated with upright chest radiographs. **b** Right pneumothorax following chest tube placement. A chest tube should be placed immediately in the multiply injured patient with a pneumothorax. A moderate-sized chest tube (32–40° in adults or 26–30° in children) is generally placed either anteriorly in the second intercostal space midclavicular line or in the fourth or fifth intercostal space midaxillary line

with reduced breath sounds and with a chest dull to percussion on one side. The neck veins may be flat because of severe hypovolemia or distended as a result of the mechanical effects of a chest full of blood [7]. With the loss of a small amount of blood (<400 mL), the diagnosis is difficult because there may be little or no change in the patient's appearance, vital signs, or physical findings. Fluid collections >200–300 mL can usually be seen on a good upright chest radiograph as blunting of the costophrenic angle. The supine radiograph is less accurate [24].

Treatment of a hemothorax consists of restoration of the circulating blood volume with transfusion of fluids or blood products through large-bore intravenous lines; control of the airway and support of the ventilation as required; and drainage of the accumulated blood from the pleural cavity. A large chest tube (36–40F) should be inserted in the fifth or sixth intercostal space in the midaxillary line and directed posteriorly and superiorly to avoid damage to a possibly elevated diaphragm. The chest tube should be connected to an underwater seal and steady suction (20–30 cm of water). If the chest tube becomes clotted and fails to drain, another chest tube should be placed rather than an attempt made to irrigate the first tube. With massive bleeding, autotransfusion of the drained blood is possible until banked blood is available [25].

Persistent hemorrhage requires surgical exploration. Thoracotomy for intrathoracic bleeding is indicated for the following: initial thoracostomy tube drainage >1500 cc of blood; persistent bleeding at a rate >200 cc; increasing hemothorax seen on chest radiographic studies; or persistent hypotension despite blood replacement with other sites of blood loss having been ruled out or the patient decompensating after an initial response to resuscitation [24]. In a few instances, emergency thoracotomy in the emergency room may be necessary for control of blood loss. However, mortality from this procedure is very high.

Flail Chest A flail chest results when there are multiple rib fractures, usually at several sites along the rib (Fig. 16.8). The resulting unstable segment of chest wall moves paradoxically during respirations—inward with inspiration and outward with expiration. A flail chest may affect respiratory ability to the point at which hypoxemia occurs. The pain associated with the respiratory effort may also compromise the ventilatory compliance of the patient. The fractured ribs may have punctured the lung, causing a tension pneumothorax or hemithorax. A problem with flail chest and hypoxemia is the underlying pulmonary contusion from the injury. The contused lung may be asymptomatic in the initial presentation but develop complications later with gas exchange. Little abnormal breathing may be apparent immediately after the injury. Later, as fluid moves into the lung with the developing contusion, lung compliance falls, and more pressure is needed to inflate the lungs. The pulmonary contusion underlying major chest wall injuries may be the primary cause of hypoxia and morbidity in patients with flail chest. Mortality in patients sustaining severe blunt chest trauma remains relatively high at 12–50% [26].

A flail chest is usually apparent on visual examination of the unconscious patient. It may not be initially

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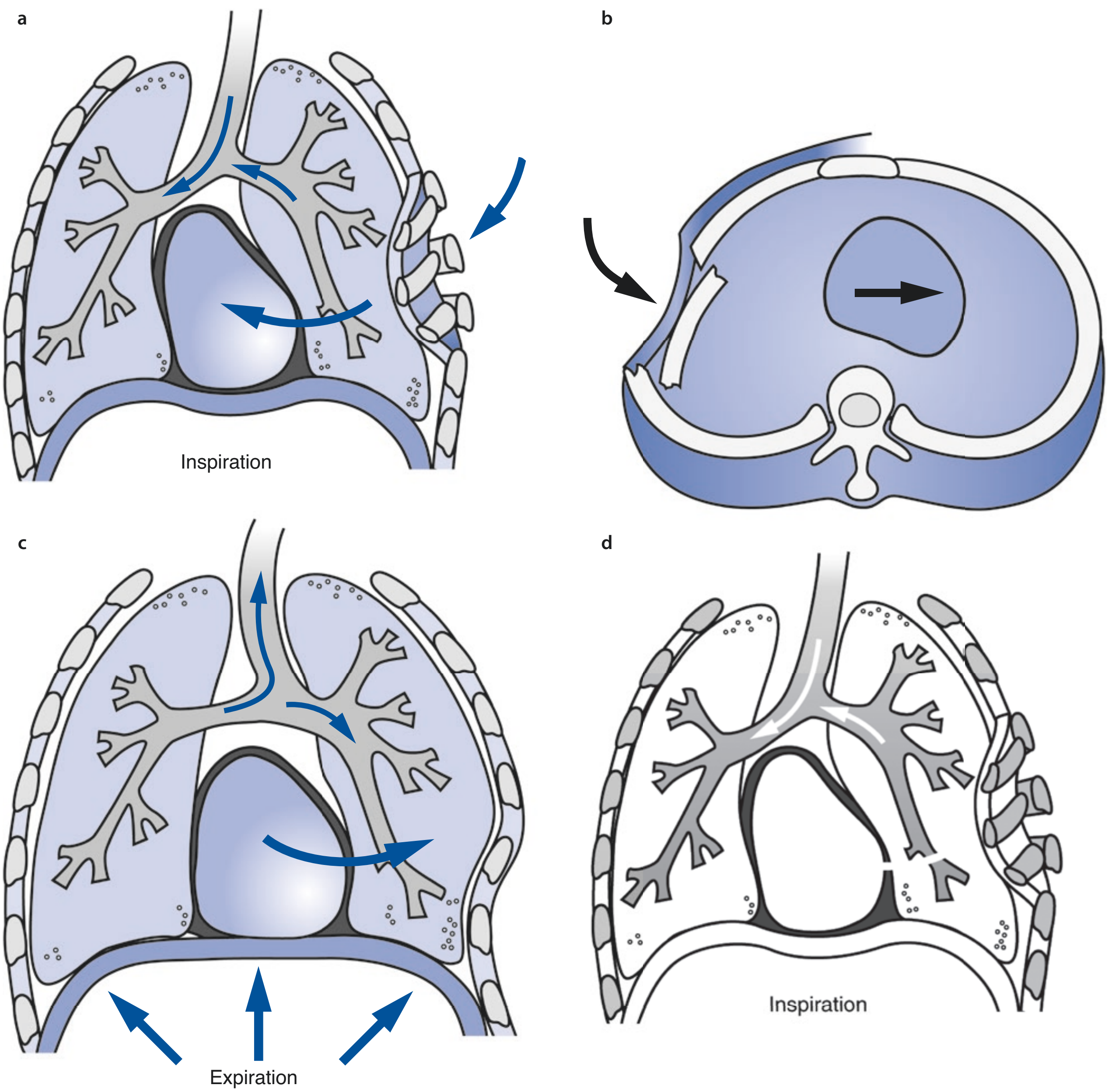


Fig. 16.8 A flail chest occurs when three or more adjacent ribs are fractured in at least two locations, resulting in a freely moving segment of the chest wall during respirations. The chest wall moves paradoxically during inspiration and expiration owing to the flail segment. **a** Upon inspiration, the flail segment sinks inward as the chest wall expands, impairing the ability to produce negative intrapleural pressure. **b** The heart and other contents of the mediastinum shift toward the noninjured side. **c** and **d** During expiration, the flail segment is pushed outward, and the chest wall cannot efficiently force air from the lungs. Air may shift uselessly from lung to lung. (Adapted from Vukich and Markovchick [77, p. 477])

apparent in the conscious patient because of splinting of the chest wall. The patient moves air poorly as a result of paradoxic breathing, and movement of the thorax is asymmetric and uncoordinated. The region of the fractures may be tender to palpation.

Recommended management of flail chest involves three treatment considerations—pain management, supplemental oxygen delivery, and ventilation control. Prolonged relief is best obtained with intercostal nerve blocks to block the pain from the fractured ribs, thereby allowing the patient to breathe deeply and cough. The use of narcotic medications must be limited to avoid respiratory depression. A volume-cycled respirator with endotracheal intubation is indicated to provide positive end-expiratory pressure (PEEP) ventilation and intermittent mandatory ventilation. This “internal splinting” with ventilatory support effectively manages the inadequate depth of ventilation, improves oxygen absorption in the segments of pulmonary contusion, and decreases atelectasis. If proper management with ventilatory assistance is initiated early, the respiratory support may be required for only 2–4 days. If management is delayed until the patient demonstrates respiratory difficulty, prolonged therapy for up to 14 days may be necessary [26]. Care and constant monitoring of the patient is always important but especially with the use of mechanical ventilation that may cause further injury resulting in pneumothorax, airway injury, alveolar damage, or ventilator-associated pneumonia.

Oxygenation After establishment of a patent airway and sustained breathing, the patient should be given supplemental oxygen. The patient may have diminished oxygen-carrying capacity as a result of injuries to the pulmonary or cardiovascular system: respiratory compromise may be due to a head injury and disruption of cerebellar reflex systems, airway distress from maxillofacial or neck injuries, or pulmonary injuries such as pulmonary contusion, flail chest, and a tension or open pneumothorax that mechanically prevents the proper delivery of oxygen to the cardiovascular system. Oxygen should be delivered through a face mask or endotracheal tube. A person breathing 100% oxygen can move five times more oxygen into the alveoli with each breath as when breathing normal air. Oxygen therapy can increase available oxygen by as much as 400% above normal [27].

Administered oxygen can increase the inspired oxygen to 8 L/min and can increase the fraction of inspired oxygen (FiO_2). A higher FiO_2 can be delivered by a Venturi mask, with the proper application of a bag and mask system. The greatest difficulty with this system is maintaining an adequate seal between the mask and face. The thumb and index finger are placed over the mask to hold the mask securely over the mouth and nose, and the other fingers are curled beneath the inferior border of the mandible. The FiO_2 can be increased in a bag and mask system with a rebreathing mask and an oxygen accumulator to deliver a high concentration of oxygen. Ventilation with the bag and mask system is difficult in patients with possible maxillofacial, cervical spine, or thoracic injuries, and the patient's airway must be stabilized with either endotracheal intubation or tracheotomy.

Endotracheal intubation helps to protect the airway and facilitates adequate lung inflation with high FiO_2 in the injured patient. Oxygen administered through the endotracheal tube should be increased to a FiO_2 of 100% (especially if the patient is comatose) until arterial blood gas measurements confirm hemoglobin saturation (PaO_2 > 60–70 mm Hg), at which point FiO_2 can be lowered to between 40% and 60% [28]. Pulmonary oxygen toxicity may result if 100% oxygen is administered continuously for 24 h; therefore, 100% oxygen delivery is acceptable only until PaO_2 levels can be ascertained. Some concern exists about the suppression of the respiratory drive with oxygen therapy, but the hypoxic drive can be reestablished following stabilization of the injured patient.

The most important mechanism of delivery of oxygen to the tissues is the hemoglobin within the erythrocytes in the cardiovascular system. In a traumatized patient, hemorrhage may decrease the available hemoglobin to the point of hypooxygenation of vital organ tissues and cell death. A normal hemoglobin of 15 g/100 mL provides transport of 20% volume of oxygen, whereas a hemoglobin of 7 g/100 mL carries only a 10% volume of oxygen, which is the critical reserve level of oxygen consumption for most tissues, especially the myocardium and brain [27]. The treatment of shock in the patient with multisystem injuries is directed toward restoring cellular and organ perfusion with adequately oxygenated blood, rather than merely restoring the patient's blood pressure and pulse rate [8].

16.3.3 Circulation

Following establishment of an adequate airway and breathing in the injured patient, the cardiovascular system of the patient must be assessed, and control of baseline circulation to the tissues must be quickly restored. The most common cause of shock in the traumatized patient is hypovolemia caused by hemorrhage, either externally or internally into body cavities. Assessment of the degree of shock is important because inadequate tissue perfusion can cause irreversible damage to vital organs such as the brain or kidneys in a short time period. During the primary assessment, a minimum of two large-bore (14–16-gauge) intravenous catheters should be placed peripherally if fluid resuscitation is required. At the time of placement of an intravenous catheter, blood should be drawn from the catheter to allow for typing, cross-matching, and baseline hematologic and chemical studies. If there is any doubt of adequate ventilation, arterial blood should be obtained for blood gas analysis.

Tissue perfusion and oxygenation are dependent on cardiac output and are best initially evaluated by physical examination of skin perfusion, pulse rate, and the mental status of the patient. Blood pressure levels are commonly used as a surrogate for cardiac output and to suspect hypovolemia, but in the emergency situation, blood pressure measurement may be an unreliable indicator of developing shock. The response of the blood pressure level to intravascular loss is nonlinear because compensatory mechanisms of increased cardiac rate and contractility, along with venous and arteriolar vasoconstriction, maintain the blood pressure in the young healthy adult during the first 15–20% of intravascular blood loss. After a blood loss of 20%, the blood pressure level may drop significantly. (In the elderly patient with less-efficient compensating mechanisms, the decline in blood pressure levels may begin to develop after a 10–15% blood loss.) The patient may arrest at an intravascular blood loss of 40% [29].

Blood pressure level may be insensitive to the early signs of shock, and a patient's blood pressure level may quickly drop following the initial assessment as compensatory mechanisms can no longer keep up with intravascular volume loss. Also, the usual baseline blood pressure level of the patient is often unknown. A patient who has a systolic pressure of 120 mm Hg but is normally hypertensive may have a significant loss, whereas a healthy young athlete may have a normal systolic pressure of 90 mm Hg, and the blood loss might be assumed to be greater than it is.

Skin perfusion is the most reliable indicator of poor tissue perfusion during the initial evaluation of the patient. The early physiologic compensation for volume loss is vasoconstriction of the vessels to the skin and muscles. The cutaneous capillary beds are one of the first areas to shut down in response to hypovolemia because of stimulus from the sympathetic nervous system and the adrenal gland through epinephrine and norepinephrine release. The release of the catecholamines causes sweating, and during palpation, the skin may feel cool and damp. The lower extremities are usually first to be affected, and the first indication of intravascular loss may be paleness and coolness of the skin over the feet and kneecaps. A check of the capillary filling time by performing a blanch test gives an estimate of the amount of blood flowing to the capillary beds. In this test, pressure is placed on the fingernail, toenail, or hypothenar eminence of the hand (to evacuate blood from the capillary beds), followed by a quick release of the pressure. The time required for the blood to return to the capillary beds, represented by the restoration of normal tissue color, is usually <2 s in the normovolemic patient. This indicates that the capillary beds are receiving adequate circulation [30].

The rate and character of the pulse should be assessed and is a good measure of the cardiac rate. The pulse rate is a more sensitive measure of hypovolemia than is the blood pressure, but it is affected by other factors commonly associated with the trauma situation, such as the patient's pain, excitement, and emotional response, resulting in tachycardia without underlying hypovolemia. However, in adults with tachycardia >120 beats/min, hypovolemia should be expected and investigated further. Older patients generally are unable to exceed rates of 140 beats/min in a hypovolemic state, whereas younger patients may present rates of 160–180 beats/min with severe intravascular loss. In patients who have pacemakers, are taking heart-blocking medications such as propranolol or digoxin, or have conduction abnormalities within the heart, hypovolemia may not cause tachycardia.

The most distal palpable pulse may give some indication of the blood pressure and cardiac output. Generally, if the radial pulse is palpable, the patient's systolic blood pressure is >80 mm Hg; if the femoral pulse is palpable, the patient's systolic blood pressure is 70 mm Hg or higher; and if the carotid pulse is noted, the systolic blood pressure is >60 mm Hg. Pulse rhythm and regularity may also provide clues to increasing hypovolemia and cardiac hypoxia. Cardiac dysrhythmias such as premature ventricular contractions or arterial fibrillation produce an irregular rate and rhythm, signaling the potential loss of compensating mechanisms maintaining myocardial oxygenation.

Decreased intravascular volume is immediately reflected in decreased urinary output because the compensatory mechanisms of the body decrease blood flow to the kidneys in favor of blood flow to the heart and brain. Any patient with significant trauma should always have an indwelling urinary catheter inserted to monitor urine volume every 15 min [29]. A minimally adequate urine output is 0.5 mL/kg/h, and fluid therapy should be initiated to maintain at least this level of urinary output. If the patient's injuries include pelvic fractures or blunt trauma to the groin, a urinary catheter should not be placed until the urethra has been evaluated for injury. If urethral injury is unlikely, the urinary catheter may be placed with minimal concern following a rectal examination. Classic signs of urethral injury include blood at the meatus, scrotal hematoma, or a high-ridding boggy prostate on rectal examination.

Alterations in the mental status of the trauma patient caused solely by hypovolemia are uncommon, except in the most progressive preterminal stages of intravascular fluid loss. Compensatory mechanisms maintain blood flow to the brain, and hypoperfusion to the brain does not develop until the systolic blood pressure falls below 60 mm Hg. The mental changes usually seen are agitation, confusion, uncooperativeness, anxiety, and irrationality. These alterations in mental status can also be seen in a patient with head trauma, spinal injury, drug or alcohol intoxication, hypoxia, or hypoglycemia. In the emergency situation, these other causes of mental status changes should be investigated when hypovolemia is suspected in the agitated patient who has or possibly has suffered substantial blood loss [29].

Hypovolemia caused by hemorrhage may commonly cause flat neck veins. Distended neck veins, however, suggest either tension pneumothorax or cardiac dysfunction. As discussed earlier, with tension pneumothorax, an examination of the chest may reveal absent breath sounds and a hyperresonant chest. Cardiac dysfunction results from cardiac tamponade, myocardial contusion or infarction, or an air embolus.

Cardiac tamponade presents a clinical picture that is similar to that of tension pneumothorax—distended neck veins, decreased cardiac output, and hypotension. Blunt or penetrating trauma may cause blood to accumulate in the pericardial sac. The blood in the pericardial sac results in inadequate cardiac filling during diastole, diminished cardiac output, and circulatory failure. Cardiac tamponade usually is associated with penetrating wounds to the chest that have injured the tissues of the heart. The classic Beck's triad of decreased systolic blood pressure levels, distended neck veins, and muffled heart sounds may be observed although all three are rarely seen together. The expected distended neck veins caused by increased central venous pressure may be absent because of hypovolemia. The neck veins, if distended, may become distended further during inspiration (Kussmaul's sign), and the pulsus paradoxus (lowering of the systolic pressure by >10 mm Hg on normal inspiration) may be accentuated or absent. Tension pneumothorax may mimic cardiac tamponade or, because of the nature of the penetrating injury, may develop at the same time as cardiac tamponade, thus presenting a confusing clinical presentation.

Cardiac tamponade is initially managed by prompt pericardial aspiration through the subxiphoid route (Fig. 16.9). Radiographs and physical examination may be not helpful in the diagnosis of a cardiac tamponade. A fast scan ultrasound may provide evidence of pericardiac fluid, but a high index of suspicion may be the best diagnostic asset of a developing cardiac tamponade. A positive pericardial aspiration along with a history of chest trauma is frequently the only method of making a correct diagnosis. Because of the self-sealing qualities of the myocardium, aspiration of pericardial blood alone may temporarily relieve symptoms. All trauma patients with a positive pericardial aspiration require open thoracotomy and inspection of the heart. Pericardial aspiration may not be diagnostic or therapeutic if the blood in the pericardial sac has clotted, as occurs in 10% of patients with cardiac tamponade [29].

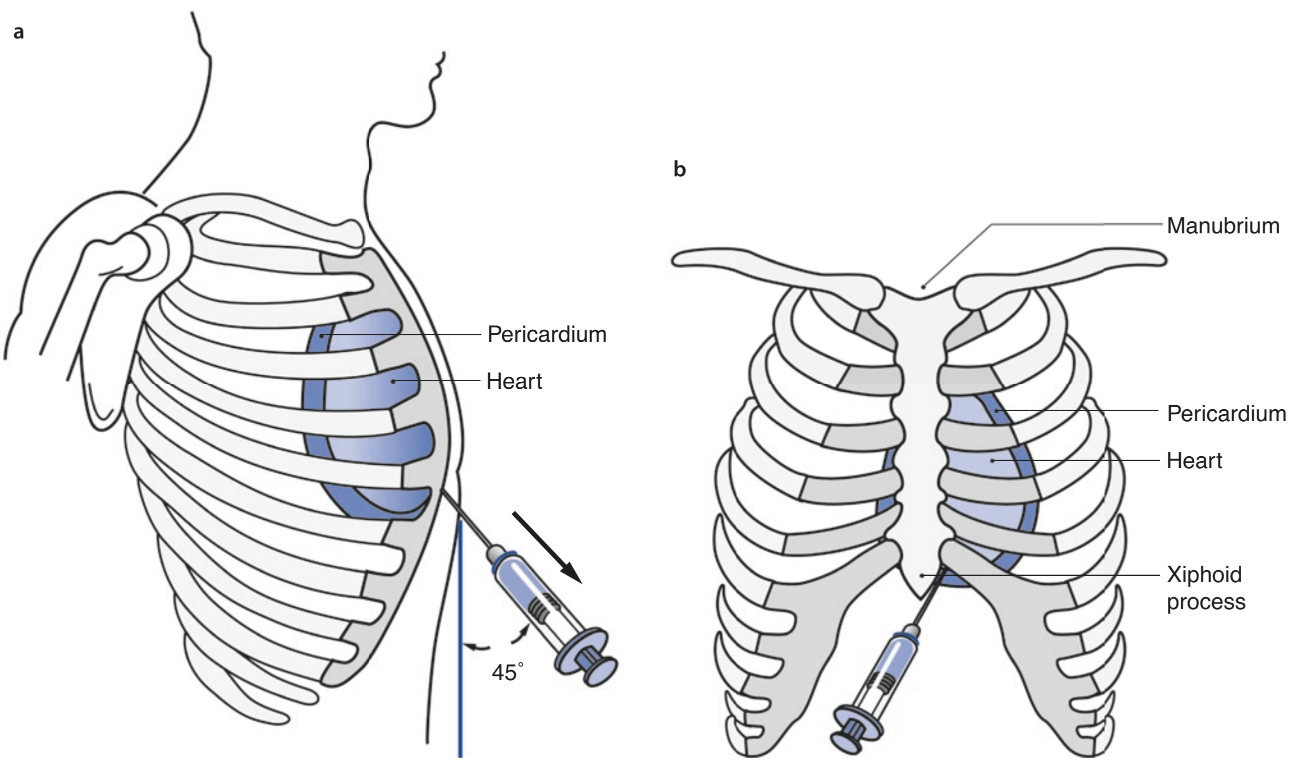


Fig. 16.9 Pericardiocentesis can be transiently lifesaving when a significant cardiac tamponade develops. **a** and **b** The patient is placed in a supine position, and a 16- or 18-gauge needle on a 60 cc syringe is introduced just to the left side of the xiphoid process. The needle should be introduced at a 45° angle to the chest wall and 45° off the midline and directed toward the posterior aspect of the left shoulder. A popping sensation may be felt as the pericardium is entered. If the blood within the pericardial sac is slightly clotted, it may interfere with the effectiveness of the procedure. Relief of a depressed systolic blood pressure level should be immediate, resulting from an increased stroke volume. The procedure may be required several times until definitive treatment can be initiated. (Adapted from Powers [15])

If aspiration does not lead to improvement of the patient's condition, only emergent thoracotomy can solve the problem unless there is another injury to the patient that has been overlooked.

Pericardial aspiration through the subxiphoid route involves the insertion of a needle, preferably covered by a plastic catheter (angiocatheter), at 90° slightly to the left of the xiphoid process. The needle is inserted until it clears the sternal border and is then directed at 45° toward the left scapular tip to directly enter the pericardium. Suction is placed on the needle hub to identify by blood return when the needle has entered the pericardial sac. If the needle is properly placed, as little as 50 cc of blood from the pericardial sac should result in a marked improvement in the patient's condition.

Control of Bleeding Hemorrhage is defined as an acute loss of circulating blood. Normally the blood volume is approximately 7% of the adult ideal body weight. A 70 kg male has approximately 5 L of circulating blood. The blood volume does not increase significantly in obese patients, and in children, the blood volume is usually between 8% and 9% of body weight (80–90 mL/kg) [7]. Bleeding may be external or internal into body cavities. Most external hemorrhage can be controlled with direct pressure to the wound. If an extremity is involved, it should be elevated. Firm pressure should be continuous, and if the dressings become soaked, they should not be removed but, rather, covered with additional dressings. Removal of a dressing may disrupt clot formation and promote further bleeding. Firm pressure on the major artery in the axilla, antecubital fossa, wrist, groin, popliteal space, or ankle may assist in the control of hemorrhage distal to the site. Pressure points should only be used if direct wound pressure is not effective alone. Pressure bandages include the use of air-pillow splints and blood pressure cuffs. Pneumatic antishock garments (PASGs) and medical (military) antishock trousers (MASTs) previously used to increase blood pressure in cases of hypotension have been found to be detrimental in some situations such as instances of vascular injuries [31]. The PASG/MAST garments are still used by some to stabilize pelvic fractures. Scalp or skin wounds may best be managed with immediate closure with large monofilament sutures (without cosmetic closure considerations) and direct pressure until the hemorrhage is controlled.

Because of the rich blood supply to the head and neck, significant hemorrhage may be associated with large scalp wounds, nasal or midface fractures, and penetrating neck wounds. In a short period of time, the scalp may lose a large amount of blood, which oozes from the galea and loose connective tissue layers. The wound can be approximated rapidly with 2-0 nonresorbable sutures without regard to cosmetic closure. Direct pressure should then be placed over the wound to control the hemorrhage and minimize hematoma formation. After the patient has been stabilized, the sutures may be removed, and a more cosmetic approach with resorbable sutures may be used to close the galeal layer and to achieve good approximation and orientation of the hair-bearing dermal and skin layers.

Nasal or midface fractures may hemorrhage from tears of the ethmoidal arteries that arise from the internal carotid system or from branches of the maxillary artery system (◘ Fig. 16.10). Most hemorrhages from facial injuries can be controlled with direct pressure or packing (◘ Fig. 16.11). Internal maxillary artery bleeding from posterior maxillary wall fractures associated with Le Fort I- or II-level fractures usually can be controlled by pressure with gauze packing for extended periods. Liquid thrombin or epinephrine may be added to the gauze packing, and the patient's head may be elevated to assist with hemostasis. If direct control is necessary, good visualization of the damaged vessel is required. Blind clamping may cause further bleeding from vessels and soft tissues, as well as nerve damage. Ligation of the external carotid artery may be required only in extreme cases; usually it is ineffective when used alone and without direct control of hemorrhage because of the collateral circulation of the face.

The potential internal sites of hemorrhage are the thoracic cavity, abdomen, retroperitoneum, and extremities. A complete physical examination with radiography and computed tomography (CT) is useful to identify hemorrhages into these areas (◘ Figs. 16.12 and 16.13). When there is no evidence of external or intrathoracic bleeding, continued severe hypovolemia is usually the result of bleeding into the abdomen or at fracture sites. Blood loss with fractures should be considered to be at least 1000–2000 mL for pelvic fractures, 500–1000 mL for femur fractures, 250–500 mL for tibia or humerus fractures, and 125–250 mL for fractures of smaller bones. A hematoma the size of an apple usually contains at least 500 mL of blood. Control of hemorrhage into internal spaces is not done in the primary survey unless the hemorrhage may have damaging effects on the cardiovascular or pulmonary system. Slow internal hemorrhage may be controlled by splinting, casting, or fixation of fractures; by the defense mechanisms of vascular occlusion, refraction, and clot formation; or by open exploratory surgery.

Hypovolemic Shock in the Patient with Multisystem Injuries The most common cause of shock seen in the patient with multisystem injuries is hypovolemia caused by hemorrhage. Virtually all multisystemic injuries are accompanied by a degree of hypovolemic shock that presents as a graded physiologic response to hemorrhage. This

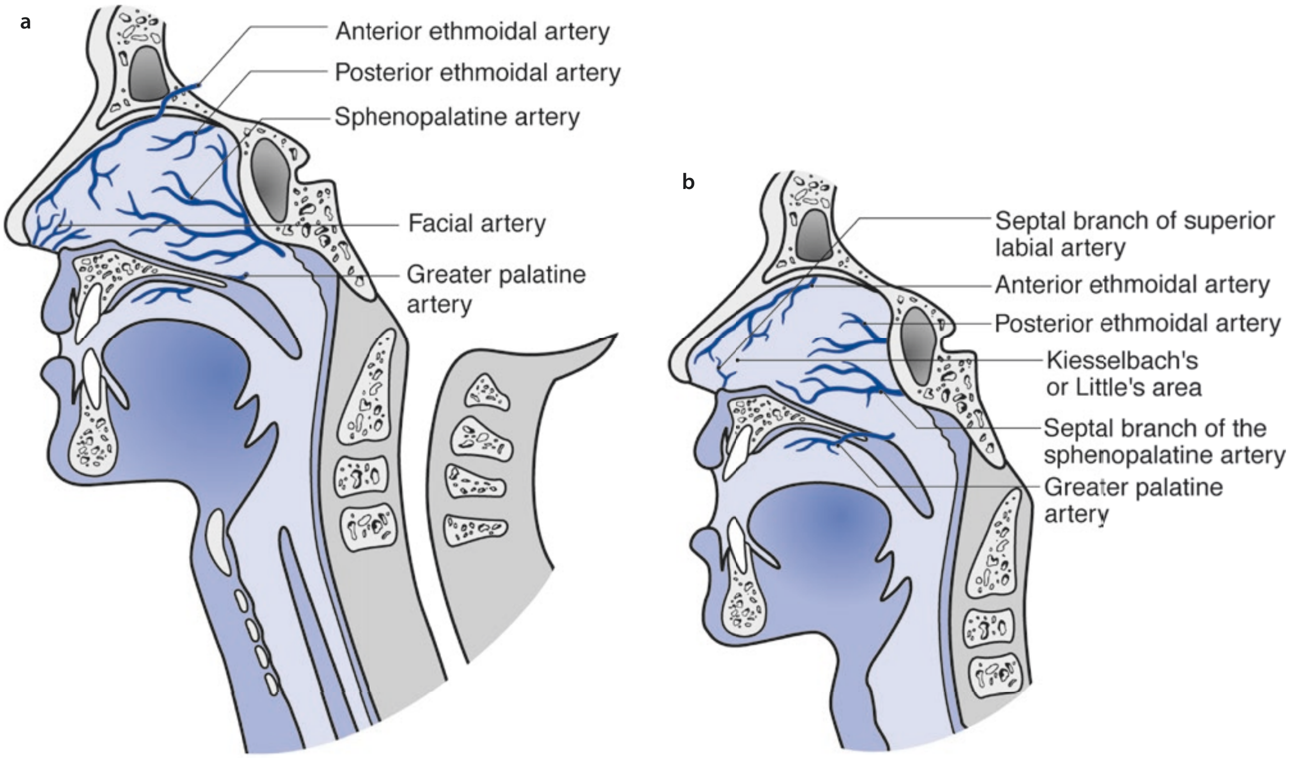


Fig. 16.10 The lateral wall of the nasal cavity **a** and the nasal septum **b** receive a rich blood supply from both the internal and external carotid artery system. The superior aspect of these structures receives a blood supply through the internal carotid system from the anterior and posterior ethmoidal arteries. The middle and inferior aspects are supplied by vessels from the external carotid artery: the facial artery and the nasopalatine, greater palatine, and sphenopalatine arteries from the maxillary artery. The region commonly referred to as Kiesselbach's or Little's area, in the anterior inferior portion of the nasal septum, receives an abundant blood supply from all the vessels and is the region where most epistaxis originates. (Adapted from Powers [15])

response can be classified based on the percentage of acute blood loss (Table 16.5).

Class I Hemorrhage: Blood Loss of up to 15% The clinical symptoms of blood loss of up to 750 mL in the 70 kg adult male are minimal. A mild tachycardia is noted, but the compensatory mechanisms of the body retain normal blood pressure levels, pulse pressure, respiratory rate, and tissue perfusion.

16

Class II Hemorrhage: Blood Loss of 15–30% Blood loss of 15–30% represents a 750–1500 mL loss in the 70 kg adult male. Clinical symptoms commonly expected with this level of blood loss are tachycardia, tachypnea, and a decrease in the difference between systolic and diastolic blood pressure or pulse pressure. The decrease in pulse pressure level is due to the elevation of catecholamines and increased peripheral vascular resistance in response to the decreased intravascular components. The increase in diastolic pressure suggests hypovolemia because there is no noticeable decrease in the systolic pressure in the early stages of blood loss. The peripheral vasoconstriction may show an elongated capillary refill time, and the skin may feel cold and moist.

Class III Hemorrhage: Blood Loss of 30–40% In the 70 kg adult male, a 30–40% blood volume loss represents a 1500–2000 mL loss, which is fairly detrimental to the survival of vital organ tissues. Patients present with the classic signs of inadequate tissue perfusion, including marked tachycardia (120–140 beats/min), tachypnea, marked vasoconstriction, a decreased systolic pressure level, diaphoresis, anxiety, restlessness, and decreased urinary output.

Class IV Hemorrhage: Blood Loss of >40% Blood losses approaching half of the intravascular volume produce an immediately life-threatening situation. Symptoms include marked tachycardia, a significant decrease in the systolic blood pressure level to <60 mm Hg, marked vasoconstriction with a very narrow pulse pressure, marked diaphoresis, obtunded mental state, and no urinary output.

Management In managing the trauma patient in shock, the speed with which resuscitation is initiated and the time required to reverse shock are the factors crucial to the patient's outcome [32]. The focus should again always be on controlling the hemorrhage, whether it be through basic measures such as pressure and elevation or through

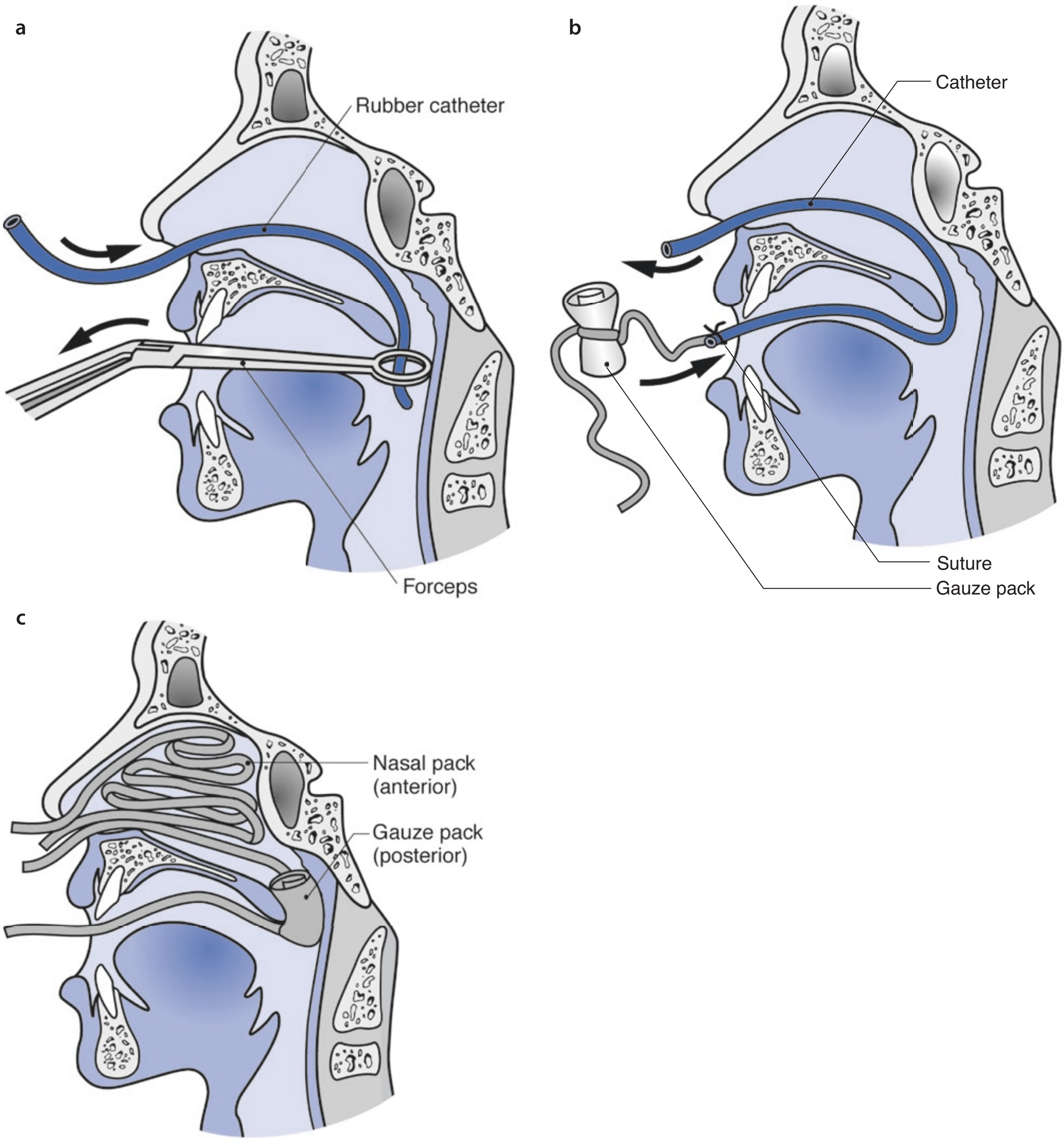


Fig. 16.11 A combined technique used for anterior and posterior packing of the nasal cavity involves the following: **a** A small red rubber catheter is introduced through the nostrils and carefully passed posteriorly along the floor of the nose until visualized in the oropharynx. Care must be taken with Le Fort II level, nasoethmoid, or other fractures involving the cribriform plate that the catheter does not pass through the fracture site into the cranial vault. Once the catheter is visualized, a forceps may be used to grasp the catheter and pull it into the oral cavity. **b** The catheter is then sutured to a tape that is secured to a wad of gauze packing material. The catheter is drawn from the nasal cavity through the nostril, pulling the gauze pack into position in the nasopharynx against the posterior aspect of the nasal cavity. **c** Once the posterior pack is in place, the anterior pack (consisting of 1 cm ribbon gauze) is packed in an orderly fashion along the nasal floor, building superiorly; this allows for easy removal and efficient packing of the nasal cavity. (Adapted from Leigh [78])

■ **Fig. 16.12** Pelvic fracture. Pelvic fractures, fractures of the femur, and multiple fractures of other long bones may cause hypovolemic shock and life-threatening blood loss, the primary site of which may be difficult to determine. Typical closed fractures of the pelvis may lose 1–5 L of blood, femur fractures 1–4 L, and arm fractures 0.5–1 L from the vasculature

rapid imaging/surgical intervention. Aggressive and continued volume resuscitation is not a substitute for definitive control of hemorrhage. Two large-bore (16-gauge or larger) short angiocatheters are a minimum for beginning fluid therapy. Initial attempts should be made to place percutaneously the catheters in the basilic or cephalic veins in the antecubital fossa of both arms. Percutaneous placement of femoral, jugular, or subclavian vein catheters may also be used if there are no abdominal injuries or pelvic or femur fractures. When the patient is in an extreme hypovolemic state, placement of percutaneous catheters may be difficult; venous cut-down procedures to expose the saphenous vein provide venous access for fluid resuscitation. Flow is directly dependent on the catheter's internal diameter and is inversely dependent on its length. Therefore, two catheters of the same length and diameter, whether inserted peripherally or centrally, give the identical flow rate, but a longer central catheter delivers a lower possible maximum flow rate than does a shorter peripherally placed catheter. A central line through the subclavian or internal jugular vein routes usually takes longer to place than a peripheral line and may require disruption of other resuscitation measures such as chest compressions during placement. Furthermore, a central line may complicate resuscitation of the trauma victim by causing or aggravating a developing pneumothorax or hemothorax or other potential complications associated with its placement. Therefore, peripheral intravenous lines are the access of choice in the primary management of the trauma patient.

Circulatory support and proper oxygenation of tissues are indicated by adequate systolic and diastolic blood pressure levels, pulse pressure levels, pulse rate characteristics, and capillary refill times. The clinical observations of these parameters are difficult to quantitate, as is measuring improvement of stabilization of the circulatory system.

■ **Fig. 16.13** Femur fracture. Fat embolism syndrome is usually associated with major fractures of long bones, especially of the femur. The patient typically does well for 24–48 h and then develops progressive respiratory and central nervous system deterioration. Concomitant laboratory value changes include hypoxemia, thrombocytopenia, fat in the urine, and a slight drop in hemoglobin. Fat enters the venous sinusoids at the fractured site and becomes lodged in the lung alveoli

Adequate urine production is a predictable sign of renal function, except in cases in which urine production may be enhanced by the use of diuretics as decreased in chronic renal failure. For this reason, urinary output is a prime indication of resuscitation and patient response. A Foley catheter should be placed in the bladder as soon as possible to measure urinary flow. There are three contraindications for the insertion of a Foley catheter, and the catheter should not be placed until all have been ruled out. These contraindications in the traumatized patient are the presence of blood at the urethral meatus, of hemorrhage into the scrotum, and of a high-riding prostate (■ Fig. 16.14a) [33–35]. Attempts to pass a catheter up an injured urethra can convert an incom-

Table 16.5 Estimated fluid and blood losses[a]

	Class I	Class II	Class III	Class IV
Blood loss (mL)	Up to 750	750–1500	1500–2000	>2000
Blood loss (% vol)	Up to 15	15–30	30–40	>40
Pulse rate	<100	>100	>120	>140
Blood pressure	Normal	Normal	Decreased	Decreased
Pulse pressure	Normal or increased	Decreased	Decreased	Decreased
Respiratory rate	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
Fluid replacement[b]	Crystalloid	Crystalloid and blood	Crystalloid and blood	Crystalloid

Adapted from the American College of Surgeons Committee on Trauma [8, p. 98]
[a]Based on the initial presentation of a 70 kg man
[b]The guidelines in the table are based on the "3-for-1" rule. This rule is derived from the empiric observation that most patients in hemorrhagic shock require as much as 300 mL of electrolyte solution for each 100 mL of blood loss. Applied blindly, these guidelines can result in excessive or inadequate fluid administration. For example, a patient with a crush injury to the extremity may have hypotension out of proportion with his or her blood loss and requires fluids in excess of the 3:1 guidelines. In contrast, a patient whose ongoing blood loss is being replaced by blood transfusion requires <3:1. The use of bolus therapy with careful monitoring of the patient's response can moderate these extremes

plete laceration into a complete laceration and can introduce infection into the perineal and retropubic hematoma. A rectal examination should be performed in all trauma patients with suspected pelvic trauma before placement of a catheter. If a pelvic fracture is present, one should consider a urethrogram prior to placing a Foley catheter. With posterior urethral disruption, the prostate may be forced superiorly by a hematoma; if the prostate cannot be palpated, a urethral injury should be suspected (Fig. 16.14b) [36].

The initial intravenous resuscitation fluid used in most hospitals is a balanced electrolyte solution such as lactated Ringer's solution or 0.9% normal saline. During prolonged shock, isotonic fluid is lost from the intravascular and interstitial spaces to the extracellular space. Initially, the patient should be given 2 L of intravenous fluid (20 mL/kg for a pediatric patient) rapidly over 10–15 min and then observed. If this maneuver does not raise the systolic blood pressure to at least 80–100 mm Hg, the patient requires additional fluid, blood, and control of blood loss. There is still controversy about the use of colloids (albumin, plasma protein fractions) and artificial plasma expanders (dextran, hetastarch) to treat hypovolemia secondary to trauma. The cost of these materials does not appear to be justified by clinical data [37, 38]. Extensive meta-analysis shows a trend toward increased mortality with the use of colloids over crystalloids [39]. However, there is still support for their use, particularly if blood replacement is delayed or inadequate or in patients with severe head injuries that require fluid restriction therapy to control rising intracranial pressure (ICP) levels.

Most patients respond to initial fluid administration, but this improvement may be transient—especially in patients who have lost >20% of their blood volume [7].

With excess hemorrhage, red blood cells must be replaced in the intravascular circulation to maintain an optimum oxygen-carrying capacity. The safest type of blood to administer is blood that has been fully cross-matched. Obtaining fully cross-matched blood may require 30 min or more and is usually not possible immediately in the trauma situation. Type-specific blood is a safe alternative and can usually be ready within 5–15 min. With whole blood loss and requirements for early blood replacement, O-negative blood may also be given in patients with excessive hemorrhage [5]. The O blood group is the most common and contains no cellular antigens. Theoretically, O-negative blood can be given to persons regardless of the individual's blood group with minimal risk of antigen-antibody hemolytic reaction. However, no more than 4 U of O-negative blood should be given [40].

Fresh frozen plasma (FFP) is frequently used as a volume expander and provides all of the clotting factors except platelets. It also provides opsonins and some complement factors, which may be deficient in patients with severe trauma or shock. During massive transfusions, FFP is often given after an elevation of INR,

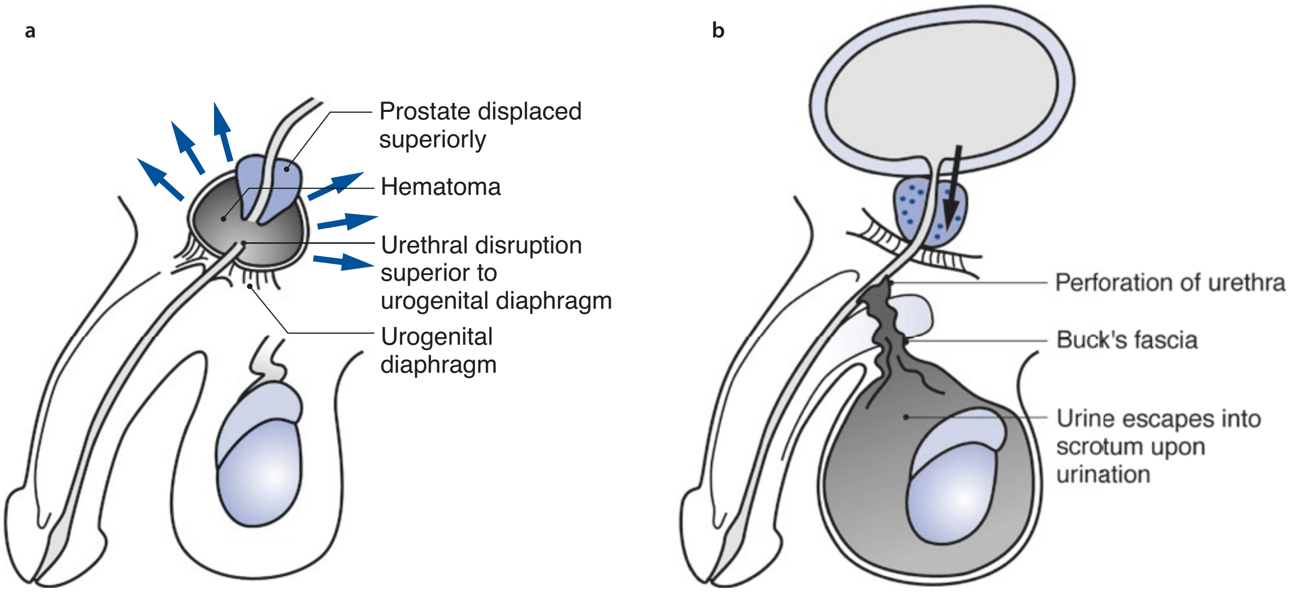


Fig. 16.14 **a** The contraindications for placement of a Foley catheter in the trauma patient are the presence of blood at the urethral meatus, hemorrhage into the scrotum, and a high-riding prostate. Blood at the urethral meatus may be a significant enough disruption of the urethra to prohibit passage of a catheter safely. **b** The development of a hematoma or urine collection within the scrotum typically results from an anterior urethral disruption from perineal blunt trauma with a perforation of Buck's fascia. With a posterior urethral disruption, the prostate may be forced superiorly by the developing hematoma. (Adapted from Powers [15])

especially if packed red blood cells are administered in an attempt to prevent coagulation abnormalities. Additionally, platelet levels below <100,000/mm^3 may be an indication for a platelet transfusion [41].

The restoration and maintenance of body temperature is also important in the trauma patient. Appropriate body temperature increases the response to resuscitative measures and decreases the risk of worsening coagulopathy with massive transfusion. The use of body warmers and fluid warmers is strongly recommended.

If the patient initially responds to therapy, blood may not be required immediately, but the patient will require blood if hypovolemic shock continues to develop. A blood sample should be sent to the blood bank as soon as possible for full cross-matching. The patient who is resuscitated initially with O-negative unmatched blood or type-matched blood should be switched to fully cross-matched blood as soon as reasonably possible to limit the risks of hemolytic reactions [42]. Such blood is compatible within the AB-positive and Rh blood groups but may contain minor antigenic incompatibilities. Ideally, the amount of blood given should be equal to the amount lost by the patient, but this is difficult to assess in the trauma patient. In critically ill or injured patients, the ideal hemoglobin is 10 g/dL (hematocrit of 30% or higher).

If the patient does not respond to initial fluid resuscitation and blood transfusions, either surgical intervention is required to control continued hemorrhage, or the initial diagnosis of hypovolemia is incorrect. Measurement of the central venous pressure with a catheter or evaluation of the neck veins may assist with the assessment of hypovolemic shock. Those patients with exsanguinating hemorrhage should have a low central venous pressure, and those with other causes of shock should have a normal or elevated central venous pressure [7]. The ultimate hemodynamic criterion in the treatment of hypovolemic shock is the patient's response. Adequate resuscitation is achieved when adequate oxygenation, circulation, and urine output are restored.

A patient being treated for hypovolemic shock is usually placed in a head-down or Trendelenburg's position to empty the venous side of the peripheral circulation back to the heart. Frequently, the patient with multisystem trauma has injuries to the abdomen or chest that may interfere with the respiratory capacity if the patient is in Trendelenburg's position. Alternatively, both of the patient's legs can be elevated, while the patient's trunk is maintained in a supine position [43].

16.3.4 Neurologic Examination

Upon completion of the assessment of the cardiovascular system and control of any external hemorrhage, a brief neurologic evaluation is performed to establish the patient's level of consciousness and pupillary size and reaction. This brief neurologic examination quickly identifies any severe CNS problems that require immediate intervention or additional diagnostic evaluation. A lack of consciousness with altered pupillary reaction to light requires an immediate CT scan of the head and possible management with mannitol or fluid restriction. Be aware of any medications that the patient may have received or drugs he or she may have taken that may affect the pupils. Some individuals will have anisocoria, a condition with an unequal size of the pupils, and provide a false examination of neurologic trauma.

The American College of Surgeons Committee on Trauma recommends the use of the mnemonic AVPU [7, 8]. In this system, each letter describes a level of consciousness in relation to the patient's response to external stimuli: *a*lert, responds to *v*ocal stimuli, responds to *p*ainful stimuli, and *u*nresponsive.

A more detailed quantitative neurologic examination is part of the secondary survey of the trauma patient. The primary survey establishes a baseline; if the patient's neurologic condition varies from the primary to the secondary survey, a change in intracranial status may be present. A decrease in the level of consciousness may indicate decreased cerebral oxygenation or perfusion.

The reactivity of the pupils to light provides a quick assessment of cerebral function. The pupils should react equally. Changes represent cerebral or optic nerve damage or changes in ICP. Further changes in pupil reactivity or levels of consciousness may be due to alterations in ventilation or oxygenation status. The most common causes of coma or depressed levels of consciousness are hypoxia, hypercarbia, and hypoperfusion of the brain [42]. Depressed levels of consciousness and narrow pinpoint pupils may result after an opiate overdose. Treatment requires the narcotic antagonist naloxone hydrochloride, 0.4 mg initially. Care should be taken to avoid a quick violent withdrawal phase in the opiate abuser; this is accompanied by profound distress, nausea, agitation, and muscle cramps.

Both hypoglycemia and hyperglycemia can cause depressed levels of consciousness. If a quick blood glucose level cannot be obtained (and depending on other injuries), the patient can be given an immediate bolus of 25 g of glucose to manage critical hypoglycemia. A benefit of the glucose load is the hyperosmolar status that may, for a short time, reduce cerebral edema, if present [44].

16.3.5 Exposure of the Patient

The patient should be completely disrobed so that all of the body can be visualized, palpated, and examined for injuries or bleeding sites. The clothing must be completely removed, even if the patient is secured to a spinal backboard. The easiest method is to cut the clothing down the midline of the torso, arms, and legs to facilitate the examination and assessment. The patient must be quickly covered with warming blankets, and there must be use of a patient warming system, use of fluid warmers, and/or increase in the room ambient temperature to avoid cooling of the injured patient. Frequent careful reevaluation of the injured patient's vital signs is important to monitor the patient's ability to maintain an adequate airway, breathing, and circulation (Fig. 16.15).

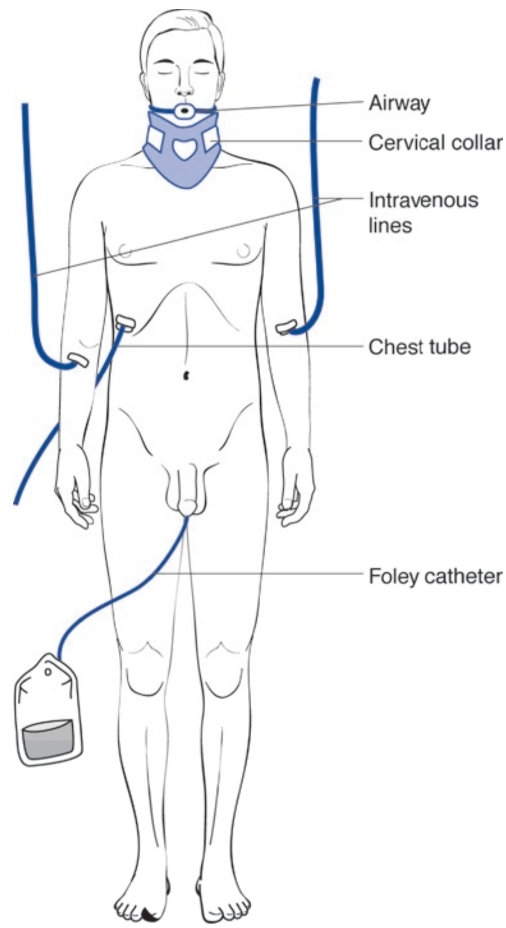


Fig. 16.15 The primary assessment of the patient with multiple injuries requires evaluation and maintenance of an adequate airway with cervical protection, adequate breathing (including the placement of chest tubes to correct alterations in normal lung and chest wall physiologic conditions), and adequate circulation and hemodynamics, with the placement of two large-bore intravenous lines peripherally and the insertion of a Foley catheter after possible urethral damage is ruled out. The patient should be totally exposed so that the entire body can be examined for injuries. (Adapted from Powers [15])

16.4 Secondary Assessment

Importance

- Secondary assessment includes an abbreviated patient history and objective evaluation of systems from head to toe.
- Systems: head and skull, maxillofacial area and neck, chest, spinal cord, abdomen, genitourinary, extremities.
- Systematically progressing from head to toe reduces the possibility of missing injuries that are not immediately apparent.
- Due to the increase in incidence, opioid overdose should be considered during the secondary survey.

The secondary assessment does not begin until the primary assessment has been completed and management of life-threatening conditions has begun. During the secondary assessment, the patient's vital signs and condition should be constantly monitored to evaluate the therapeutic interventions initiated during the primary assessment and to further assess the patient for any other life-threatening problems not evident during the primary survey. Changes in the patient's vital signs, respiratory and circulatory status, and neurologic functions are expected in the first 12 h [7]. The secondary assessment includes a subjective and objective evaluation of the injured patient. If at any time during the secondary survey the patient has a significant change in status, a return to the primary survey and management is indicated.

A subjective assessment should include a brief interview with the patient, if possible. A brief health history can be useful, including medications; allergies; previous surgery; a history of the injury; and the location, duration, timeframe, and intensity of the chief complaint. Obviously, the comatose patient cannot provide useful subjective information, but family members, bystanders, or other victims may provide some details. It is important to discuss with the EMS personnel and review their reports for pertinent details of their findings at the scene and during the patient transport.

The objective assessment should involve inspection, palpation, percussion, and auscultation of the patient from head to toe. Each segment of the body (head and skull, chest, maxillofacial area and neck, spinal cord, abdomen, extremities, and neurologic condition) is evaluated to provide a baseline of the patient's present condition. Special procedures such as peritoneal lavage, radiographic studies, and further blood studies may be done at this time.

16

16.4.1 Head and Skull

Primary injuries to the head and skull may involve lacerations, abrasions, avulsions, and contusions of the scalp; fractures of the cranium and cerebral contusions; and intracranial bleeding from lacerations or shearing injuries. The brain may also suffer secondary insults from intracranial bleeding, hypoxia, and ischemia. Hypoxia is due to an impaired delivery of oxygen to the brain, whereas ischemia can result from arterial hypotension, elevated intracranial pressures (ICP), or pressure on intracranial vessels from expanding hematomas. Increased ICP can result in herniation of the brain from the cranial vault (Fig. 16.16). The secondary insults of hypoxia and various forms of ischemia are usually preventable. About one-half of patients with head inju-

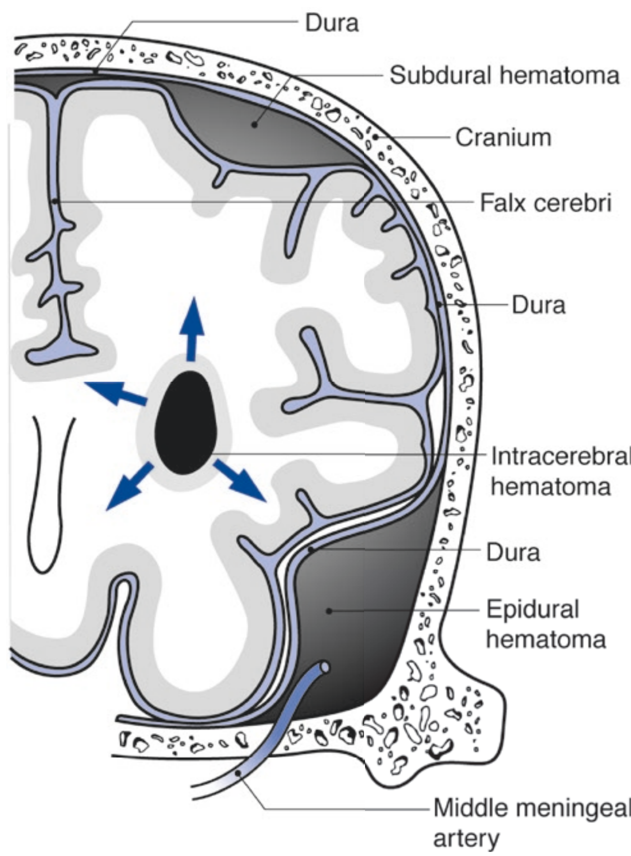


Fig. 16.16 Mass lesions commonly associated with head trauma include epidural hemorrhage, subdural hemorrhage, and intracerebral hemorrhage. A subdural hematoma is usually caused by venous bleeding with progressive loss of neurologic function. The epidural hematoma is usually associated with skull fractures near the temporoparietal region, with tearing of the middle meningeal artery. (Adapted from Powers [15])

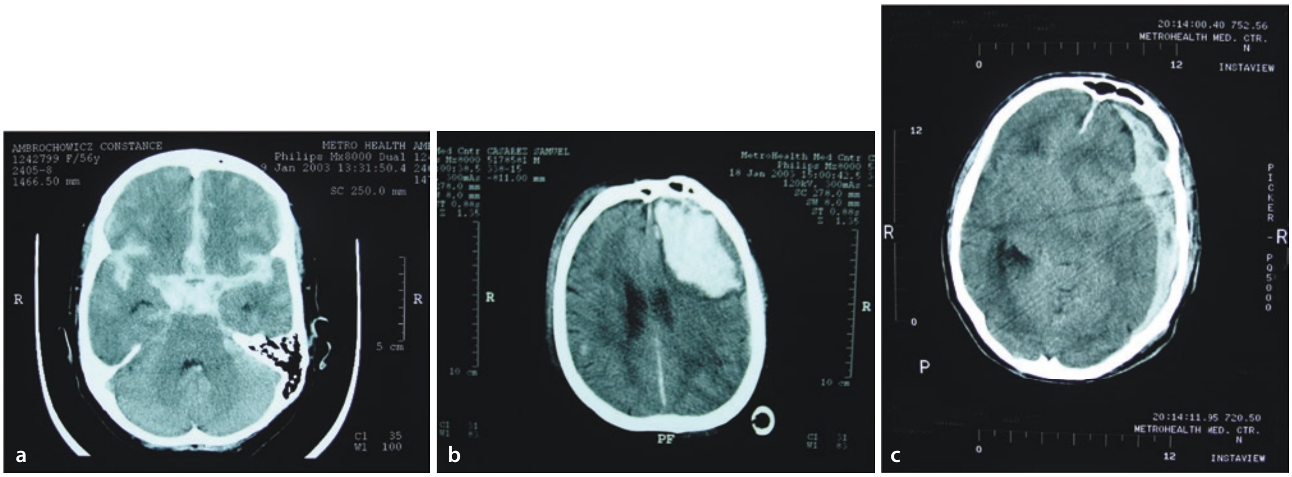


Fig. 16.17 Computed tomography scans demonstrating anatomic variances associated with intracranial bleeding. **a** Subarachnoid hemorrhage is defined as blood within the cerebral spinal fluid and meningeal intima and probably results from tears of small subarachnoid vessels. Blood is spread diffusely through the arachnoid matter and usually does not cause mass effect, but may predispose a patient to cerebral vasospasm. **b** Intracerebral hemorrhage is formed deep within the brain tissue and is usually caused by shearing or tensile forces that mechanically stretch and tear deep small-caliber arterioles as the brain is propelled against irregular surfaces in the cranial vault. Note the surrounding edema and mass effect. **c** Subdural hematomas are blood clots that form between the dura and the brain. They are usually caused by the movement of the brain relative to the skull, as is seen in acceleration-deceleration injuries. Note the considerable shift of midline to the right

ries have some degree of reversible injury caused by increased ICP that can be controlled with aggressive management. Failure to prevent increased ICP is the most frequent cause of death in hospitalized patients with a severe head injury. Hypertension with concomitant bradycardia may indicate increasing ICP (Cushing's phenomenon). Hypotension with tachycardia usually indicates blood loss. Shock is rarely associated with the primary neurologic injury, and systemic sources of blood loss should be investigated. The classic findings of Cushing's phenomenon are usually present <25% of the time, even when the ICP is found to be >30 mm Hg. A value >15 mm Hg is considered abnormal.

Accurate continual neurologic assessment and examination for mass lesions with CT scans are rapid noninvasive techniques that are not life-threatening for the patient with a head injury and that establish a baseline examination for future studies. When an intracranial injury is suspected, CT scans can quickly and easily be used to diagnose localized intracranial hemorrhage (Fig. 16.17), contusion, foreign bodies, and skull fractures. In addition, secondary effects of trauma such as edema, ischemia, infarction, brain shift, and hydrocephalus can be seen on CT scans. In the acutely traumatized patient, CT scans can be used to diagnose intracerebral and extracerebral blood collections with nearly 100% accuracy. A significant mass lesion can cause cerebral ischemia by elevating ICP or by compressing vascular structures. A CT scan should be done immediately following stabilization of the injured patient, rather than waiting for signs of an expanding intracranial hematoma. Indications for a CT scan include seizure activity, unconsciousness lasting for more than a few minutes, abnormal mental status, abnormal neurologic evaluation, evidence of a skull fracture found on physical examination, and a history of head trauma. A CT of the head can be obtained in all patients with blunt head trauma who have experienced a loss of consciousness or mild amnesia and even those with normal neurologic findings [45].

Extreme care should always be taken when moving a patient with head trauma to the CT machine because of the high incidence of associated cervical spine fractures in patients with head and facial traumas [46]. If trauma to the spine is suspected, the cervical spine should be immobilized before the patient is moved, and the CT examination should be extended to study the cervical spine as well. In addition, any suspected facial injuries should be examined by extending the CT examination inferiorly—as low as the inferior border of the mandible. Unfortunately, in many cases, evaluation and treatment of facial injuries must be delayed for a significant time, which means that the patient is needlessly transported back to the radiology department for further studies because of failure to initially extend the CT examination.

As ICP increases above normal, a fairly standard progression of neurologic abnormalities ensues, involving sections of the brain sequentially: the cerebral cortex, producing an altered state of consciousness; the midbrain, producing dilation and then fixation of the pupils, initially on the side of the lesion, with varying

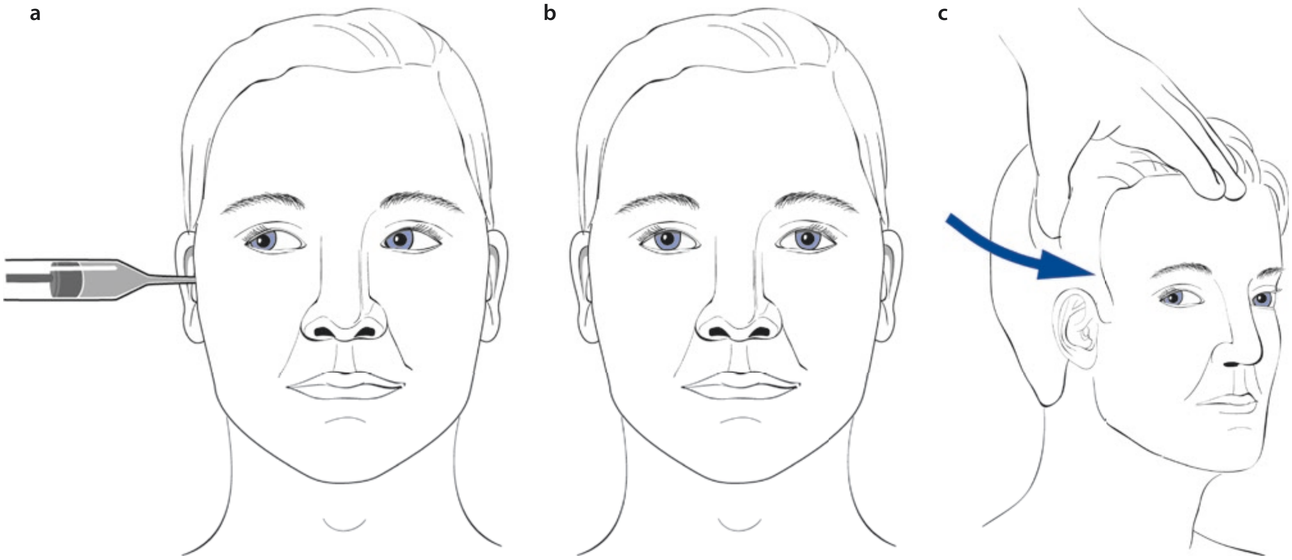


Fig. 16.18 Responses that test the third, sixth, and eighth cranial nerves, as well as ascending brainstem pathways from the pontomedullary junction to the mesencephalon. **a** The caloric response (oculovestibular maneuver) involves the placement of cold water into the ear. In a comatose patient, the eyes should tonically deviate toward the irrigated ear. **b** Patient at rest. **c** In the oculocephalic response (doll's eye reflex) in comatose patients, the head is turned from the midline, and there is a reflex movement of the eyes in the opposite direction of head rotation. (Adapted from Powers [15])

degrees of bilateral hemiparesis; the pons, resulting in a loss of the corneal reflex and the occurrence of the doll's eye reflex (Fig. 16.18); and the medulla, producing, in sequence, apnea, hypotension, and death.

The physical examination of the head should include an examination of the scalp for lacerations and foreign bodies. Because of the rich vascular supply of the scalp, especially in children, scalp injuries may result in significant blood loss. Lacerations may overlie an injury to the cranium, or intracranial hemorrhage may be present. An untreated scalp wound with a cranial injury may eventually act as a port for bacteria to enter the injured area, causing meningitis or a brain abscess. The head should be examined for signs of a basilar skull fracture: hematoma over the mastoid process behind the ears (Battle's sign); hemotympanum; cerebrospinal fluid (CSF) rhinorrhea, or otorrhea; and subscleral hemorrhage. Whenever a basilar skull fracture is suspected, a nasogastric tube should not be used because the tube may inadvertently pass into the cranial vault.

The neurologic examination should be brief and should evaluate the level of consciousness, motor and cranial nerve function (suggestive of developing mass lesions), brainstem findings, and trends in the neurologic status. Alcohol and drug intoxication are frequently associated with injured patients in the trauma situation and may complicate the neurologic examination. A decreased level of consciousness should not be attributed to alcohol or other drugs until intracranial pathologic conditions have been ruled out.

The GCS (discussed above) provides a simple method of grading consciousness and functional capacity of the cerebral cortex (see Table 16.1). It can be used both in the field and as a reassessment tool to assess brain function, brain damage, and patient progress, based on the three behavioral responses: eye opening, best verbal response, and best motor response. Two regions of the brain, if injured, can produce unconsciousness; the cerebral cortices bilaterally and the brainstem reticular activation system regardless of the cause of injury can also depress the level of consciousness [7].

Examination of the motor function is part of the GCS, which gives information about any asymmetry of function. The conscious patient should be asked to move the extremities in response to commands. An inability to do so may represent damage to the limb or spinal cord. In the unconscious patient, deep tendon reflex and plantar response testing can assess both sensory input and motor output. Of special concern are abnormal posturing and nonpurposeful movement to stimulus. Abnormal flexor activity (decorticate) involves flexion of the forearms on the chest with flexion of the wrists and fingers; in abnormal extensor posturing, the arms, hands, and fingers are extended with the hands abducted. In both cases, the lower extremities are extended, and no attempt is made to localize the point of stimulation. Although bilateral extensor plantar responses are nonspecific, a unilateral Babinski sign points to corticospinal tract damage.

Pupillary function, eye movements, and eye opening can provide information about the level of consciousness, as well as about brainstem function. The size, shape, and reactivity of the pupil to light provide information about second and third nerve function and midbrain activity. A sluggish reactive or a dilated nonreactive (blown) pupil on one side indicates compression of the third cranial nerve by brain herniation in the unconscious patient. The pupillary light reflex can be used to evaluate cranial nerve function and possible elevated ICP with brain herniation. In normal activity, when light is shone in one eye, both pupils constrict equally. The optic or second cranial nerve carries both visual and pupillary fibers. The optic nerves connect shortly after they leave the retina to form the optic chiasm. At the optic chiasm, the nasal fibers cross to join the temporal fibers from the other eye, and the visual fibers cross to the visual occipital cortex. The pupillary fibers are relayed bilaterally to the Edinger-Westphal nucleus of the oculomotor or third cranial nerve. The third cranial nerve supplies the sphincter muscle of the iris, allowing it to contract. There is also autonomic innervation of the eyes. The iris is supplied by both sympathetic and parasympathetic fibers. Stimulation of the sympathetic fibers causes the pupil to dilate and upper eyelid to elevate.

Thus, significant information about the trauma patient can be obtained by looking into the eyes. If a light is shone into the right eye and the left eye does not respond, there may be a disruption of the right optic or left oculomotor nerves. If the light is then shone into the left eye and it does not respond, a disruption of the third cranial nerve should be suspected. Pupillary dilatation of one eye may be due to a developing brain herniation on the ipsilateral side, with bilateral pupillary dilatation suggestive of significant midbrain injury or loss of parasympathetic function. Conversely, pinpoint pupils after head trauma may indicate drug overdose or loss of sympathetic tone as seen in Horner's syndrome.

The function of the brainstem may also be assessed with evaluation of the corneal reflex, which involves sensory input from the trigeminal (fifth) nerve. The oculocephalic maneuver, or test of the doll's eye reflex, requires an intact vestibular or acoustic (seventh) nerve to permit head rotation to evaluate reflexive movement of the eyes (see ◘ Fig. 16.18). Obviously this maneuver is not to be used with patients who have a suspected cervical spine injury. The oculovestibular response test evaluates the third, fourth, sixth, and eighth cranial nerves, as well as brainstem activity. In this test, the external auditory canal is irrigated with cold water; there should be full eye movement toward the ear canal lavaged with cold water. If not, there may be a disruption along any of the neural tracts or of the tympanic membrane (see ◘ Fig. 16.18).

A lumbar puncture should not be performed in patients with acute head injuries. The change in pressure associated with the removal of CSF from the lumbar region may precipitate cerebral herniation in the patient with an elevated ICP.

CSF emerging from the nose or ear is commonly associated with a basilar skull fracture. Clear or red-tinged fluid that drains from the nose or ear should be considered to be CSF. There is no reliable method available in the emergency department for distinguishing CSF from nasal mucous drainage. The use of glucose indicator sticks is associated with a high incidence of false-positive results. A useful aid may be a "ring sign." A drop of the fluid from the nose or ear is placed on a piece of filter paper. If the fluid is CSF, the blood components of the fluid remain in the center, and rings of clear fluid form around them [7].

A CT scan should be performed to determine whether there is a fracture site. The head of the bed should be elevated to 90°. If indicated, the fracture should be reduced. The leakage should cease after 7 days; if it does not, neurosurgical procedures may be indicated to repair the dural tear.

A rectal examination is an essential part of the examination of the patient with a head injury. Rectal sphincter tone is present if the injury is intracranial only; if there is no rectal tone, a coexisting spinal cord injury is present. Coexisting head and spine injuries should be suspected until proven otherwise.

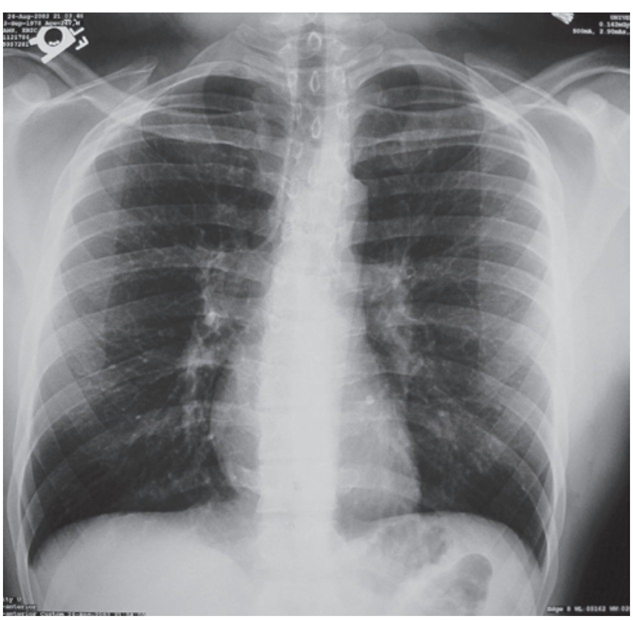
A head injury is initially classified as mild (GCS 13–15), moderate (GCS 9–12), or severe (GCS $\leq$ 8). Patients with head injuries who experience no loss of consciousness, no amnesia, no palpable fractures, and a GCS score of 15 can be discharged home to a reliable caretaker; brain imaging is unnecessary, although it is generally recommended that CT imaging be performed due to its low cost and its convenience. Patients who experience a loss of consciousness or amnesia or have a GCS score of 13 or 14 must undergo an immediate head CT. If this noncontrast study finding is negative, the patient can be discharged to a reliable caretaker. If there is a focal neurologic finding on examination, a GCS score of <13, or an intracranial lesion seen on the head CT, the patient should be admitted to an intensive care unit or neurologic observation unit for continuing care. The administration of prophylactic phenytoin at a loading dose of 18 mg/kg IV is used by some for control of possible seizure activity. Ongoing seizures may be controlled with a benzodiazepine. Neurosurgical consultation should be obtained early in the management of any significant head trauma. Patients with severe head injuries (GCS < 8) should undergo rapid sequence intubation technique for airway protection and better control of ICP. The patient's ICP is controlled using various techniques, including reverse Trendelenburg position, osmotic diuresis (mannitol), hyperventilation of the intubated patient (although there is little or no documented benefit to this procedure), sedation, pharmacologic paralysis, and phenobarbital coma (last resort). Judicious use of resuscitative fluids and control of systemic hypertension also help to control ICP.

16.4.2 Chest

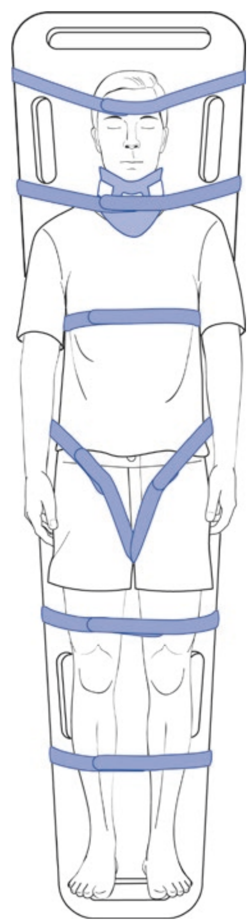
Throughout the secondary assessment of the multiply injured patient, the primary evaluation of airway, breathing, and circulation must be monitored for development of difficulties or overlooked problems. Pneumothorax, open pneumothorax, hemothorax, flail chest, and cardiac tamponade may develop after the primary assessment and must be treated accordingly. It is estimated that chest injuries are responsible for 20–25% of all trauma deaths per year in the United States [26].

The secondary assessment of chest trauma involves the evaluation of an upright chest radiograph for the presence of air in the mediastinum or under the diaphragm, widening of the mediastinum or a shift from the midline, thoracic injuries and fractures that alter lung expansion, and the presence of fluid. ◘ Figure 16.19 shows a chest radiograph of a patient without chest trauma. In most instances, the trauma patient needs to be immobilized on a backboard (◘ Fig. 16.20), and a supine film is substituted for an upright one. If a chest injury is suspected, a CT scan should also be obtained. An electrocardiogram, arterial blood gas analysis, hematocrit, and urinalysis should be obtained. Potentially lethal injuries to consider in the secondary assessment are pulmonary contusion, aortic disruption, tracheobronchial disruption, esophageal disruption, traumatic diaphragmatic hernia, myocardial contusion, and simple pneumothorax [7].

Pulmonary contusions are treated in the same manner regardless of whether there is an accompanying flail chest injury. Pulmonary contusions are common in blunt chest trauma because the capillary damage within the lungs results in interstitial and intra-alveolar edema and shunting. Pulmonary contusions and adult respiratory distress syndrome (ARDS) are the most common potentially lethal chest injuries seen in the United States because the resulting respiratory failure does not occur instantaneously but develops in 24–72 h [24]. The patient may complain of pain and dyspnea, and blood gas levels tend to deteriorate progressively over the initial 48–72 h as increasing edema develops in the alveoli. Chest radiographs reveal a developing opacification of the involved areas. Treatment involves adequate ventilation of the lungs, including chest physiotherapy, supplemental oxy-



◘ **Fig. 16.19** Normal upright chest radiograph



◘ **Fig. 16.20** Stabilization of the trauma victim for transportation is best achieved with the use of a long backboard with bindings and sand bags to control the head in a neutral position. (Adapted from Powers [15]) gen, coughing with deep breathing, and nasotracheal suction. If ventilatory assistance is required, spontaneous ventilation with intermittent mandatory ventilation (IMV) provides much better ventilation-perfusion matching, better hemodynamics, and quicker weaning than does assisted ventilation. The use of steroids is controversial [47].

Injury to large intrathoracic arteries or veins may develop with blunt or penetrating trauma; this is the most common cause of sudden death after an automobile accident or a fall from a great height [7]. Common sites of injury are the aortic root and the descending aorta at the origin of the ductus arteriosus and at the diaphragm. These injuries are fatal within a few minutes—only 15% of patients with thoracic aortic injuries are still alive on arrival at a hospital. It is not uncommon for the aortic intima and media to be fractured circumferentially, with only the adventitia and surrounding mediastinal tissues preventing fatal hemorrhage. The patient may appear clinically stable; yet, failure to recognize this vascular injury may lead to eventual death. Adjunctive signs on chest radiographs that are suggestive of thoracic vascular injury include a widened mediastinum, fractures of the first and second ribs, obliteration of the aortic knob, deviation of the trachea to the right, the presence of a pleural cap, deviation of the esophagus to the right, and a downward displacement of the left mainstream bronchus [7]. If an aortic rupture is suspected on clinical or radiographic examination, a CT angiogram or aortography should be performed. While waiting for the examination, it is important not to let the patient become hypertensive or cough or gag excessively (e.g., as may occur with the placement of a nasogastric tube).

Pain in the mediastinum needs to be investigated and usually requires a surgical consultation. Pain may be secondary to a developing pneumothorax, tracheobronchial or esophageal disruption, or free air arising from the abdomen with disruption of the diaphragm. CT scans can be useful in diagnosis and differentiation of the level of injury. A simple traumatic pneumothorax is usually best treated with a chest tube. Small pneumothorax may be observed with serial physical examination and chest radiographs in qualified centers. If the patient's condition declines, placement of a chest tube is required. Traumatic diaphragmatic hernia is suspected when bowel is seen in the chest or the nasogastric tube lies above the diaphragm in the chest radiograph or CT. Small herniations may be missed on initial examination and present as clinical problems years later. Myocardial contusion most commonly presents with sinus tachycardia, but other arrhythmias may also arise. An EKG with cardiology consultation is recommended if there is a strong suspicion that a myocardial contusion is possible.

16.4.3 Maxillofacial Area and Neck

Maxillofacial injuries may cause airway compromise from blood and secretions, from a mandibular fracture that allows the tongue to fall against the posterior wall of the pharynx, from a midface injury that causes the maxilla to fall down and back into the nasopharynx, and from foreign debris such as avulsed teeth or dentures. A large tonsillar suction tip should be used to clear the oral cavity and pharynx. An oral airway assists with tongue position; however, care must always be taken to avoid manipulation of the neck and to provide for access to the oral cavity and dentition for reduction and fixation of any fractures requiring some period of intermaxillary fixation. Neither midface fractures nor cerebrospinal rhinorrhea are contraindications to nasal intubation or nasogastric tube placement. Care must be taken to pass the tube along the floor of the nose into the pharynx, and the tube should be visualized before intubation of the trachea with an endotracheal tube or of the esophagus with the nasogastric tube. A chest CT or radiograph must be obtained to verify proper position of the tube before use.

The physical examination should begin with an evaluation for soft tissue injuries. Lacerations should be debrided and examined for disruption of vital structures such as the facial nerve or parotid duct. The eyelids should be elevated so that the eyes can be evaluated for neurologic and possible ocular damage. The face should be symmetric without discolorations or swelling suggestive of bony or soft tissue injury. The bony landmarks should be palpated, beginning with the supraorbital and lateral orbital rims, infraorbital rims, malar eminences, and zygomatic arches, and nasal bones should be palpated. Any step-off or irregularities along the bony margin are suggestive of a fracture. Numbness over the area of distribution of the trigeminal nerve is usually noted with fractures of the facial skeleton.

The oral cavity should be inspected and evaluated for lost teeth, lacerations, and alterations in the occlusion. Any teeth lost at the time of injury must be accounted for because the tooth may have been aspirated or swallowed.

The neck should also be examined for injury. Subcutaneous air may be visualized if massive injury is present; if subtle, it may be detected only by palpation. The presence of air in the soft tissues may be the result of tracheal damage or pneumothorax. Any externally expanding edema or hematoma of the neck must be observed closely for continued expansion and airway compromise. Carotid pulses should be assessed. Palpation for abnormalities in the contour of the thyroid cartilage and for the midline position of the trachea in the suprasternal notch should be performed.

16.4.4 Spinal Cord

There are >10,000 spinal cord injuries per year in the United States, usually caused by motor vehicle accidents. Multiple studies have reported a 10–20% association of cervical spine injuries with maxillofacial injuries in the multiply traumatized patient although recent data suggest no increase in cervical spine injury when facial trauma is present [48, 49]. Approximately 55% of spinal injuries occur in the cervical region, 15% in the thoracic region, 15% in the thoracolumbar junction, and 15% in the lumbosacral area [8]. Identification of cervical spine injury is essential in the management of blunt trauma because a missed injury can result in catastrophic spinal cord damage. Tetraplegia as a result of cervical spine injury is not only a tragedy for the patient; it also represents a tremendous financial burden to society [50]. According to the National Spinal Cord Injury Center Database, in July 1996, the average medical cost of the first year of a cord injury involving C1 through C4 was $417,000 (US) [50]. Patients can be expected to have medical costs of $1,350,000 over the course of their lifetime as well as lost wages and productivity. Patients can then expect a greatly shortened life span, which varies according to the age of the patient at the time of injury [48].

With an incidence of 40 per million persons per year, or approximately 12,400 events annually, traumatic spinal cord injury (TSCI) has reached epidemic levels in modern society. Despite improvements in early recognition and treatment, TSCI remains a costly problem for healthcare in the United States with direct medical expenses ranging from 500,000 to two million dollars for one patient over the course of their lifetime.

The causes of TSCI in the United States are broken down as follows:

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- Motor vehicle accidents: 48%
- Falls: 16%
- Violence: 12%
- Sports accidents: 10%
- Other: 14%

Multiple risk factors for TSCI have been identified. Historically, the most frequent population affected by TSCI have been young males with a median age of 22. However, in 2010, data shows that the average age has increased to 37 years. Males still make up a large majority of cases, alcohol plays a role in approximately 25% of TSCI, and underlying spinal disease can make some patients more susceptible to TSCI. Multiple studies have reported a 10–20% association of cervical spine injuries with maxillofacial injuries in the multiply traumatized patient, although data suggest no increase in cervical spine injury when facial trauma is present [70, 71]. Most spinal cord injuries are found in association with injury to the vertebral column including fracture, dislocation, ligamentous injury, and disruption or herniation of the intervertebral disc. Injury occurs as a direct result of the force and direction of the sustained trauma which produces pathologic flexion, extension, rotation, and/or compression of the spine. The stability of the spinal cord and risk for further spinal injury are directly related to the type of injury sustained. A description of the mechanism of injury, especially high-velocity accident, may give clues to a possible injury of the spine such as a whiplash injury. The patient may experience little discomfort from major injury to the chest, abdomen, and extremities as a result of sensory loss from a spinal injury. Because of the loss of sympathetic tone with cervical injuries, the patient may present with a systolic blood pressure level of 70–80 mm Hg without the tachycardia, cool extremities, poor perfusion, and decreased urinary output noted in the patient with hypovolemic shock. Neurologic shock is due to dilatation of the arterial system, loss of muscle tone, and loss of reflexes. The absence of neurologic deficit does not exclude injury to the cervical spine. A complete series of cervical radiographs should be obtained and read prior to the removal of stabilization. If a helmet is worn by the victim, the helmet should be secured to the long spine board with 8 cm cloth tape, and cervical spine radiographs should be taken and cleared for cervical spine injury before the attempted removal of the helmet.

Management in the emergency department prioritizes life-threatening injuries such as systemic bleeding, airway compromise, or pneumothorax taking precedence over spinal cord injury. In the patient with a spinal cord injury, as with all acute trauma patients, vital signs including heart rate, blood pressure, respiratory status, and temperature require ongoing monitoring. Physical examination of the patient with a suspected spinal injury should be done carefully, with the patient in a neutral position and with minimal movement of the spine and head (see ◘ Fig. 16.20). The presence of an unstable cervical spine injury must be considered in the evaluation and resuscitation of every patient with injuries associated with blunt trauma. The catastrophic physical consequences of irreversible quadriplegia, as well as the huge economic costs required to care for this lifelong disability, require that great care must be taken to rule out unstable cervical spine injury. The patient should be treated as if there has been an unstable injury to the nerves, bone, muscles, and other structures of the neck until there is positive clinical and radiographic evidence that there is no injury. The neck and spine should be carefully examined for deformity, edema, ecchymosis, muscle spasm, and tenderness while being carefully supported to avoid further damage associated with an unstable cervical neck injury. Patients with high cervical cord injury may breathe poorly and may require airway suction or intubation. Respiratory mechanical support may be needed, with one-third of patients with cervical injuries requiring intubation within the first 24 h. Rapid sequence intubation with inline spinal immobilization is the preferred method when an airway is urgently required; however, if time is not an issue, intubation over a flexible fiber-optic laryngoscope may be a safer option. Arterial oxygenation monitoring should be continued, as hypoxia in the setting of spinal cord injury has been shown to adversely affect neurologic outcome. Hypotension can occur secondary to blood loss from other injuries or from blood pooling in the extremities which lack sympathetic tone secondary to neurogenic shock. Prolonged hypoperfusion can also adversely affect neurologic outcome in TSCI patients.

The neurologic examination of the patient with a spinal injury is similar to that of the patient with closed head trauma. The mental status, motor function, sensation over dermatomes, brainstem reflex, and spinal reflexes should all be evaluated and charted. The patient should be carefully examined for rectal tone and bladder control as evidence of autonomic function. Hypoventilation caused by paralysis of the intercostal muscles results from injury to the lower cervical or upper thoracic spinal cord. If the upper or middle cervical spine is injured, the diaphragm will also be paralyzed as a result of involvement of the C3 though C5 spinal cord segments. Abdominal breathing and the use of the respiratory accessory muscles will be evident [7].

Bachulis and colleagues evaluated 4941 trauma victims between February 1981 and July 1985 and found that 1923 (39%) had radiographs taken of their cervical spines [51]. Injuries to the cervical spine were detected in 94 patients (5%). Ninety of these patients had cervical spine fractures; four had a disruption of the cervical longitudinal ligaments without bony injury and were quadriplegic. In the study, the overall incidence of cervical spine injury in the trauma patient was 2%. Neurologic deficit did not develop in any patient with a neurologically intact spinal cord at the time of admission. The researchers found that, of the 94 patients, there were 65 alert patients with no neurologic deficits who had unstable cervical spine injuries. Without exception, these patients complained either of neck pain or of pain on palpation of the neck. Other studies have reported that no alert patient without neck pain was found to have any cervical injury [51]. Fischer concluded that a screening radiographic examination of the cervical spine is not indicated in the alert, sober, and cooperative patient with no complaints of neck pain and no tenderness to palpation of the neck, even when significant injury is present; however, the author does recommend screening for all patients with decreased levels of consciousness and a history of an injury that could have conceivably injured the cervical spine, for all patients with neurologic deficits compatible with cervical origin, and for all patients with neck pain or tenderness [51]. Cervical spine stabilization and radiographic examination is required for all patients with severe injuries which might distract and mask neck pain and tenderness. Cervical spine injuries may result from axial loading, flexion, extension, rotation, lateral bending, and distraction or combinations of these mechanisms of injury (◘ Fig. 16.21).

In the study by Bachulis and colleagues, lateral cross-table cervical spine radiographs were obtained in all injured patients and demonstrated cervical spine injury in 70 patients but not in the other 24, for an unacceptable false-negative rate of 26%. The authors recommended that all patients at risk for cervical spine injury must have a complete initial radiographic examination, including lateral, anteroposterior, odontoid, and right and left oblique views of the cervical spine. CT scanning was found to be the most useful modality to confirm a cervical spine injury in those patients with a suspected injury to the cervical spine not confirmed on plain film radiographs. They recommend the use of CT scans of the neck for patients with a possible neck injury and associated head injury that requires a CT scan of the brain, for patients in whom radiographic visualization of C6 or C7 are difficult, and for patients with a suspected cervical injury that is not detected in screening radiographs [46]. A study by Griffen and colleagues concluded that spinal imaging is often performed in trauma patients regardless of suspected TSCI if the mechanism of trauma is severe enough. Historically, a full set of cervical spine films was required on all trauma patients before a cervical collar could be removed; however, in modern trauma practice, patients are now stratified into high- and low-risk categories based on NEXUS or Canadian C-spine guidelines. Patients who cannot be clinically evaluated secondary to intoxication, obtundation, or confusion are assumed to have TSCI until proven otherwise. Plain radiographs are historically the first method of assessment of suspected traumatic vertebral or spinal cord injury; however, with access to rapid computed tomography imaging, a majority of trauma centers will omit these studies in favor of quicker transport for CT scanning. Several prospective case series report a higher sensitivity of helical CT for detecting spinal fractures when compared with plain radiographs [75]. Another advantage of CT scanning over multi-view plain radiographic imaging is that the study can be completed without moving the patient out of supine position. CT also provides some assessment of the paravertebral soft tissues, and perhaps the spinal cord as

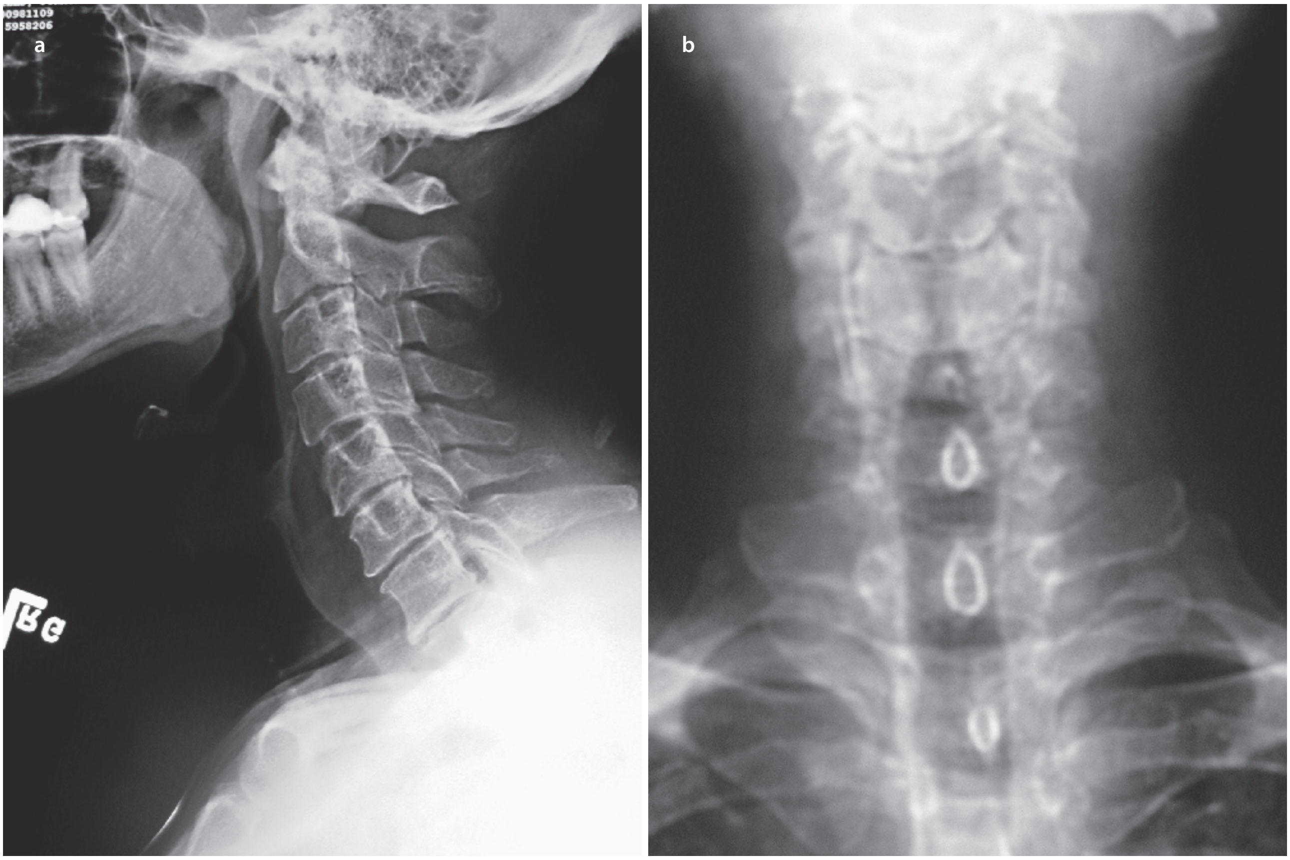

Fig. 16.21 Normal plain film cervical radiographs: **a** lateral; **b** anteroposterior

well, although with suspected soft tissue spinal injury, rapid MRI should be considered once other life-threatening injuries have been ruled out/treated. CT scanning of the cervical spine should replace plain film studies in blunt trauma patients completely [52]. Up to 50% of C-spine injuries seen on CT radiographs are missed on plain neck radiographic C-spine series due to the difficulty in obtaining a clear view of the cervical spine with plain films.

Visualization of all seven cervical vertebrae is important (see Fig. 16.21). The shoulders must be distracted inferiorly by pulling down on the arms to provide a clear view of the spinal anatomy from C6 through T1. It is important that a clear view of the spine at the C6 and C7 level be obtained without obstruction by the shoulders to obtain a proper diagnostic study. If visualization of C6 and T1 cannot be obtained, the radiographic view may be improved by placing the arms in a "swimmer's position," with downward traction on one arm and upward traction on the other and the radiograph beam aimed through the axilla of the upward arm. CT should be used for further evaluation of detected or suspected fractures, for evaluation of questionable plain films, and to complete radiographic examination of areas not well visualized by plain films. The lower cervical spine often is not well visualized on radiographs, even with use of the swimmer's position, and a CT scan is frequently required. Radiographs should be examined for fractures and fracture dislocations of the spine by evaluating the anteroposterior diameter of the spinal canal; the contour and alignment of the vertebral bodies; displacement of bony fractures of the laminae, pedicles, or neural fascicles; and soft tissue swelling [18]. Three-way cervical views (anteroposterior, oblique cervical, and lateral cervical) plus an open-mouth odontoid view or a CT scan of the neck coupled with adequate cervical spine immobilization during evaluation and resuscitation should allow the cervical spine to be viewed safely.

On a lateral cervical spine radiograph, the soft tissue thickness between the pharynx and osseous C3 should be <5 mm. An increase in this area suggests a fracture. The distance may vary with inspiration or expiration [7]. On the lateral view, the features to be examined are the general contour of the spine, the vertical alignment of the anterior and posterior margins of the vertebral bodies, the midlaminar line, the width of the spinal column, and evidence of compression or fracture of individual vertebrae. On anteroposterior views, the height and alignment of the spinous processes and the interspinous

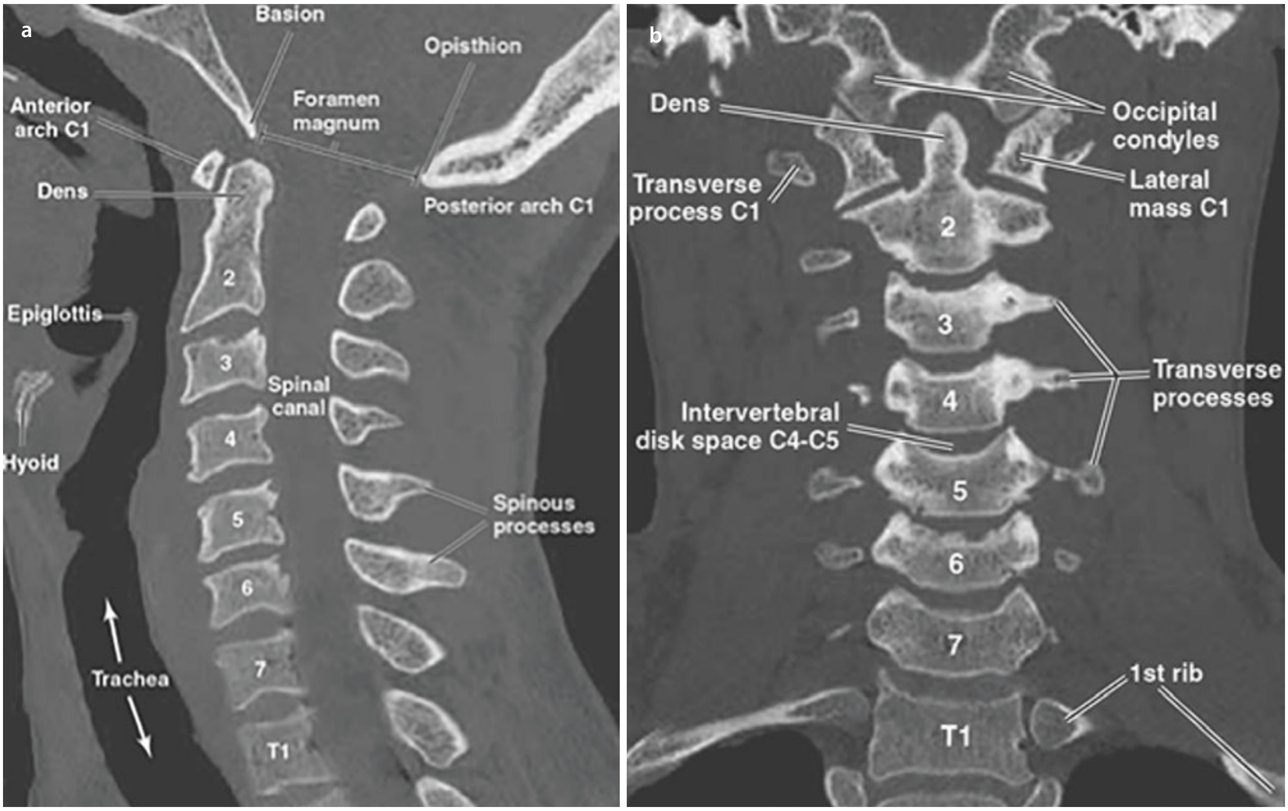

Fig. 16.22 Normal CT scan: **a** lateral; **b** anteroposterior. Radiographs should be examined for prevertebral edema, subluxation, widening of the interspinous distance, widening of the atlantodental interval, bony fractures, malalignment, or jumped facets (McKinnis and Mulligan [79])

distances are examined. The discovery of any findings suggesting the presence of a cervical spinal injury mandates the use of protective measures. It has been demonstrated that a stabilization device such a cervical collar allows significant movement of the cervical spine [53]. The recommended stabilization for patients with cervical fractures is a cervical collar in combination with a long spinal board. Appropriate head holders or sandbags should be used bilaterally to support the neck laterally, and the head should be secured with an 8 cm cloth tape across the forehead and around the board (see Fig. 16.20). Obviously, maintaining a stable airway is critical in patients who have suffered significant head and neck trauma. Cervical neck stabilization and protection as well as a nasal trumpet or similar airway protection device may be indicated to maintain a patent airway. If the airway becomes unstable, endotracheal intubation, nasotracheal intubation, tracheotomy, or cricothyroidotomy should be performed, ensuring that the cervical spine continues to be stabilized.

Patients with imaging/physical exam confirmed TSCI require urgent neurosurgical consultation to manage efforts at decompression and stabilization as well as admission to an intensive care unit for monitoring and treatment of potential acute, life-threatening complications (Fig. 16.22).

16.4.5 Abdomen

With abdominal trauma, the physical examination is an informative portion of the diagnostic evaluation. Penetrating wounds must be identified, and many surgeons believe that the safest management of penetrating wounds is a laparotomy although surgical management of penetrating wounds continues to evolve [7]. The abdominal girth should be measured at the umbilicus soon after admission to establish a baseline against which to evaluate possible intra-abdominal bleeding. Abdominal rigidity and tenderness are important signs of peritoneal irritation by blood or internal contents, and they may be the main indications for a laparotomy of a patient injured by blunt trauma. Rectal and pelvic examinations are essential if there is a question of pelvic or perineal injury. A nasogastric tube should be passed, if possible, into the stomach to remove gastric contents.

Plain films have limited value in abdominal trauma. They can be useful in localizing foreign bodies, bony structures, and free air with the use of anteroposterior and cross-table views.

The use of diagnostic peritoneal lavage (DPL), once a standard diagnostic test used in blunt and occasionally penetrating abdominal traumas, has decreased significantly with the advancement in CT and ultrasonography. DPL is indicated in patients with a history of blunt abdominal trauma and increasing pain, patients with unexplained hypovolemia following multiple trauma, patients who are candidates for laparotomy but who have questionable findings, and patients who have experienced severe trauma and who may require an extended period under general anesthesia [7]. Absolute contraindications to DPL are a history of multiple abdominal operations and obvious indications for an exploratory laparotomy—free air, evisceration, and/or penetrating trauma. A DPL is usually performed with a sterile intravenous catheter inserted percutaneously through a small midline incision about 2.5–4 cm below the umbilicus. *The procedure should be modified to a supraumbilical approach for patients with a pelvic fracture and suspected retroperitoneal hematoma or pregnant females* [63]. The catheter is advanced into the pelvis after the bladder has been emptied. If no blood, bile, or intestinal fluid is aspirated, the abdominal cavity is irrigated with 1 L of saline. The fluid is then drained from the abdomen through the intravenous tubing. It is generally felt that the presence of 100,000 red blood cells or 500 white blood cells per cubic millimeter after blunt trauma is sufficient to make a laparotomy mandatory (Table 16.6).

Table 16.6 Parameters for evaluation of peritoneal lavage fluid

Positive	20 mL gross blood on free aspiration (10 mL in children)
	≥100,000 RBCs/mm^3
	≥500 WBCs/mm^3 (if obtained ≥1 h after the injury)
	≥175 U amylase/100 mL
	Bacteria (determined with Gram's stain)
	Bile (by inspection of chemical determination of bilirubin content)
	Food particles (microscopic analysis of strained or spun specimen)
Intermediate	Pink fluid on free aspiration
	50,000–100,000 RBCs/mm^3
	100–500 WBCs/mm^3
	75–175 U amylase/100 mL
Negative	Clear aspirate
	≤50,000 RBCs/mm^3
	≤100 WBCs/mm^3
	<75 U amylase/100 mL

Adapted from Powers [15]
RBC red blood cell, *WBC* white blood cell

CT scanning of the abdomen is also acceptable if the patient is stable and emergent laparotomy is not indicated. The advantages to CT include that it is noninvasive; it is capable of discerning the presence, source, and approximate quantity of intraperitoneal hemorrhage; and it occasionally can demonstrate active bleeding. CT scanning coincidentally evaluates the retroperitoneum—an area not sampled by DPL—as well as the vertebral column and can be readily extended above or below the abdomen to visualize the thorax or pelvis. It is helpful in the evaluation of hematuria and, if used early enough, in determining renal artery injury. Disadvantages include suboptimal sensitivity for injuries of the pancreas, diaphragm, small bowel, and mesentery. Injuries of the small bowel and mesentery can have profound morbidity and even mortality if not diagnosed early. In the absence of hepatic or splenic injuries, the presence of free fluid in the abdominal cavity suggests an injury to the gastrointestinal tract and/or its mesentery and mandates early surgical evaluation and possible intervention. Complications also can result from intravenous contrast administration. *Reports have demonstrated that removing the use of oral contrast media does not lead to an increased incidence of missed bowel injury; therefore, eliminating the use of oral contrast media allows for a more rapid treatment of the patient* [63, 64]. CT is contraindicated in patients that are hemodynamically unstable in shock [63]. The cost can also be significant, especially if established indications are not followed.

16.4.6 Focused Assessment with Sonography for Trauma (FAST) Exam

Ultrasonography or focused assessment with sonography for trauma (FAST) exam has rapidly become an integral diagnostic component in trauma centers. The primary purpose of the FAST examination is to assess the trauma patient for the presence of pathologic pericardial, intrathoracic, or intraperitoneal free fluid which appears as a hypoechoic or anechoic collection. FAST examination also aids in decreasing the time required for the initial evaluation of trauma patient, as well as limits exposure to ionizing radiation.

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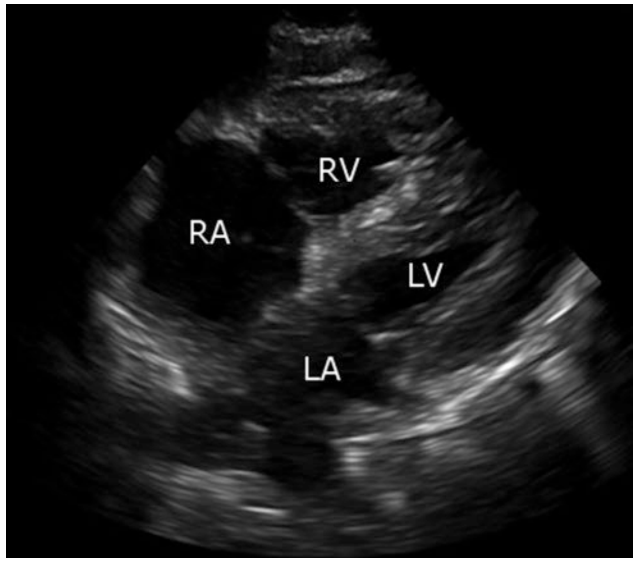
FAST examination utilizes established views to evaluate the pericardial, peritoneal, and pleural cavities. The standard order of evaluation is as follows: pericardial, right flank (Morison's pouch), left flank (peri-splenic), and pelvic (retrovesical) views. Following this progression aids in ensuring that pericardial tamponade, the most acute, life-threatening injury among those identifiable by ultrasound, is found first, as well as ensuring that all elements of the exam are not inadvertently left out.

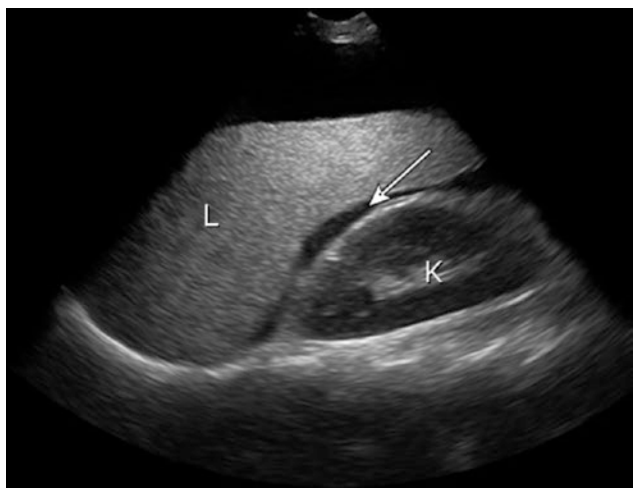
The pericardial exam is accomplished primarily utilizing a subcostal view. The probe is placed in the subxiphoid area and aimed toward the patient's left shoulder. With this approach, all four cardiac chambers and the pericardium can be seen (◘ Fig. 16.23).

Obtaining adequate images using the subcostal view can be made difficult by patients' body habitus, a tender or distended abdomen, a large amount of stomach gas, or a prominent xiphoid process. Alternative orientations such as a parasternal long view (through the rib spaces) can be utilized in these scenarios.

The abdominal portion of the FAST exam is utilized to identify free fluid in specific, dependent locations in the peritoneal cavity. Visualized fluid is assumed to be blood and is taken as a sign of injury in the acute traumatic patient (◘ Fig. 16.24).



◘ **Fig. 16.23** LA left atrium, LV left ventricle, RA right atrium, RV right ventricle



◘ **Fig. 16.24** Arrow denotes an echoic stripe of free fluid between the kidney (K) and the liver (L) in Morison's pouch

Ultrasonography is portable, easy to use, noninvasive, and inexpensive and spares the patient from exposure to ionizing radiation. Also, ultrasound exams are easily repeatable at the bedside, thus enhancing the physicians' ability to perform serial reassessments on trauma patients. FAST examination is effective at diagnosing hemopericardium and evaluating the IVC and patient fluid status, intraperitoneal free fluid, hemothorax, and, when utilizing a separate probe, pneumothorax.

While there are many positive attributes to a FAST examination, it is not without limitations. Limited sensitivity precludes the use of ultrasound as a definitive test to rule out intra-abdominal injury [72]. The sensitivity of FAST examination for intraperitoneal hemorrhage ranges from 63% to 100% [73]. There are also a number of injuries not detectable by ultrasound. FAST examination cannot discern diaphragmatic tears, bowel perforations, pancreatic lesions, mesenteric trauma, or any abdominal injury which does not produce free fluid in amounts detectable by ultrasound (>200 mL). Also, ultrasound cannot distinguish urine from blood, which gives the exam a lower sensitivity and specificity in major pelvic trauma [74]. Finally, ultrasound is limited by patient comorbidities such as patients with severe obesity, subcutaneous emphysema, and hyperinflated lungs.

Overall, ultrasonography can serve as an accurate and rapid test and is a less expensive diagnostic screening tool than are DPL and CT. FAST is the standard screening examination performed on trauma patients; however, it is most helpful when positive, in which case it decreases the time to definitive treatment. It is important to remember that secondary to the limited sensitivity, especially in penetrating trauma, ultrasonography is not a definitive tool to rule out major intra-abdominal or intrathoracic injury. Secondary to this, hemodynamically stable patients with a concerning mechanism of injury or physical examination findings are evaluated with additional imaging studies (generally CT scan) or a period of observation with serial physical and ultrasound examinations.

Ultrasonography carries a host of advantages:

- It is a portable instrument that can be brought to the bedside in the trauma resuscitation area.
- Studies of the pericardial and intraperitoneal spaces can be accomplished in <5 min.
- Sensitivity in detecting as little as 100 mL to, more typically, 500 mL of intraperitoneal fluid ranges from 60% to 95% in most recent studies, and specificity for hemoperitoneum is excellent [54].
- Unlike DPL, ultrasonography can rapidly gauge the mediastinum, is noninvasive, and can be performed serially and by multiple technicians.
- Unlike CT scanning, ultrasonography does not pose a potential radiation hazard and does not require administration of contrast agents.
- Performing focused ultrasonographic examinations with an abdominal trauma patient does not require the skill of a board-certified radiologist, which allows ultrasonography to be more readily accessible to injured patients. Accuracy correlates with length of training and experience, but expertise can be readily accomplished in emergency medicine and surgical training programs [55].
- Overall, ultrasonography can serve as an accurate and rapid test and is a less expensive diagnostic screening tool than are DPL and CT.

However, there are disadvantages to the use of ultrasonography, including the following:

- It does not image solid organ parenchymal damage, the retroperitoneum, or diaphragmatic defects very well.
- It is technically compromised by the uncooperative agitated patient, as well as by obesity, substantial bowel gas, and subcutaneous air.
- Indeterminate studies require follow-up.
- Ultrasonography is less sensitive and more operator dependent than is DPL in revealing hemoperitoneum and cannot distinguish blood from ascites.
- Ultrasonography (as well as DPL) may not detect the presence of solid organ parenchymal damage if free intraperitoneal blood is absent, as in subcapsular splenic injury [56].
- Finally, ultrasonography is poor for detecting a bowel injury in which hemorrhage tends to be inconsequential, and failure to diagnose hollow viscous perforation in a timely manner can have catastrophic results.

Table 16.7 presents indications, advantages, and disadvantages of ultrasonography, DPL, and CT in blunt abdominal trauma.

16.4.7 Genitourinary Tract

The perineum should be examined for contusions, hematomas, lacerations, and urethral bleeding. A rectal examination should assess for the presence of blood within the bowel lumen, a high-riding prostate, presence of blood or pelvic fractures, and quality of sphincter tone. A vaginal examination should be performed in patients if injury is suspected. Pregnancy tests should be performed on all females of childbearing age.

When an injury to the genitourinary tract is suspected, urologic consultation is required to further evaluate and diagnose the extent of injury. The major cause of urethral ruptures is blunt trauma. Approximately 10% of patients with a pelvic fracture have an associated posterior urethral rupture. The force of the injury causes

Table 16.7 Indications, advantages, and disadvantages of DPL, ultrasonography, and CT in blunt abdominal trauma

	DPL	Ultrasonography	CT
Indication	Document bleeding if ↓ BP	Document fluid if ↓ BP	Document organ injury if BP normal
Advantages	Early diagnosis and sensitive; 98% accurate	Early diagnosis; noninvasive and repeatable; 86–97% accurate	Most specific for injury; 92–98% accurate
Disadvantages	Invasive; misses injury to the diaphragm or retroperitoneum	Operator dependent; bowel gas and subcutaneous air distortion; misses diaphragm, bowel, and some pancreatic injuries	Cost and time; misses diaphragm, bowel tract, and some pancreatic injuries

Adapted from the American College of Surgeons Committee on Trauma [8, p. 166]
BP blood pressure, *CT* computed tomography, *DPL* diagnostic peritoneal lavage

a shearing effect between the urethra and the urogenital diaphragm [34]. Anterior urethral ruptures are also commonly associated with blunt trauma, *penetrating injuries, or instrumentation, while posterior urethral injuries are commonly concomitant with pelvic fractures* [65]. Most of these injuries occur in men [57].

Blood at the urethral meatus is the single best indicator of urethral trauma [35]. *Other classic indications of urethral trauma are a high-riding prostate on rectal examination and perineal and/or scrotal ecchymosis. With any of these signs, imaging is indicated using retrograde urethrogram. This imaging should be performed before the attempted placement of the urethral catheter* [65]. The meatus must be carefully inspected for even the slightest amount of blood before inserting a urethral catheter. As is discussed above, attempts to introduce a Foley catheter up an injured urethra can convert an incomplete laceration into a complete laceration with a subsequent retropubic or perineal hematoma [33]. A rectal examination must be performed on all patients with a suspected pelvic injury. With posterior urethral disruption, the prostate may be forced superiorly by a hematoma. If the prostate is not palpable, a genitourinary injury should be suspected [33].

Absence of blood at the meatus and palpability of the prostate on rectal examination are sufficient evidence to allow the passage of a urethral catheter. If resistance is noted, the catheter should be removed. Retrograde urethrography is the best method to establish continuity of or damage to the urethra [33].

Urine should be obtained and evaluated for the presence of blood. A urinalysis with 10 or more red blood cells on a high-power field is suggestive of a urinary system injury. Hematuria is the best indicator of renal injury, *but the degree of hematuria does not correlate with degree of injury because disruption of the ureteropelvic junction, arterial disruption, or thrombosis and a variety of other severe injuries can be present without hematuria* [65]. If the patient with a blunt injury is stable but has hematuria, a CT scan can be used to accurately visualize the genitourinary system and abdominal and retroperitoneal contents.

Sexual assault is reported to be the fastest growing violent crime in the United States. Approximately 40% of rape victims report having sustained physical injury; of those, 54% receive medical care in a hospital emergency department [62]. The responsibility of the medical personnel is not to determine if a rape has occurred—rape is a legal term, not a medical term, but to obtain a thorough history, careful examination, and prompt treatment of injuries. Rape kits are available for collection of materials and maintain a “chain of evidence.” Ideally, a rape crisis counselor or specially trained social worker stay with the patient and arrange follow-up counseling [61].

16.4.8 Extremities

Pelvic fractures, fractures of the femur, and multiple fractures of other long bones may cause hypovolemic shock and life-threatening blood loss, the primary site of which may be difficult to determine. Typical closed fractures of the pelvis may lose 1–5 L of blood, femur fractures 1–4 L, and arm fractures 0.5–1 L from the vasculature [58]. Certain extremity injuries are considered life-threatening because of associated complications—massive open fractures with ragged dirty wounds; bilateral femoral shaft fractures (open or closed); vascular injuries, with or without fractures, proximal to the knee or elbow; crush injuries of the abdomen and pelvis; major pelvic fractures; and traumatic amputations of the arm or leg [7].

Physical examination should consist of inspection and palpation of the chest, abdomen, pelvis, and all four extremities. Areas of tenderness, discoloration, swelling, and deformity should be inspected, and proper radiographs should be obtained. All peripheral pulses should be examined for evidence of vascular injury. Pulse rates should be equal; any abnormality of distal pulse rate suggests a vascular injury and must be explained. Doppler examination of the extremity is useful, but angiography is the best test for definitively evaluating a suspected vascular injury when the diagnosis is in doubt [7].

Direct pressure should be used to control hemorrhage, and fractures should be splinted as quickly as possible. Splints should generally include joints above and below the site of injury. Prompt orthopedic consultation should be obtained.

Fat embolism syndrome is usually associated with major fractures of long bones, especially of the femur. The patient typically does well for 24–48 h and then develops progressive respiratory and CNS deterioration. Concomitant laboratory value changes include hypoxemia, tachypnea, tachycardia, thrombocytopenia, fat in the urine, and a slight drop in hemoglobin. A petechial patch may be present. Fat enters the venous sinusoids at the fractured site and becomes lodged in the lung alveoli. Fat embolism syndrome has been reported to occur with 30–50% of major long-bone and pelvis fractures [59]. However, with the current coordinated management of multiply injured patients, the incidence of both fat embolisms and ARDS is decreased by expeditious femoral shaft and pelvic fracture treatment [56]. The primary treatment is ventilatory assistance. Therapy with steroids and acetylsalicylic acid has been shown to be helpful, possibly because of a reduction of platelet aggregation.

With a better understanding of fluid and electrolyte therapy, early aggressive management of hemorrhagic shock and prompt surgical treatment are now possible. However, in the interest of acute resuscitation, orthopedic injuries are often overlooked initially and are treated at a later time. When these injuries involve the spine, pelvis, or femur, immobilization of the patient is necessary for the purpose of traction. In immobilized patients with unstable fractures, there is an increased morbidity caused by respiratory failure or sepsis with related multiple organ failure. The severely injured patient with orthopedic fractures who survives the acute phase of treatment generally undergoes a prolonged course in the intensive care unit. This leads to morbidity secondary to decreased musculoskeletal function (e.g., muscle wasting, stiff joints, loss of limb length) caused by delays in fracture stabilization and subsequent patient mobilization [60]. Studies have shown that early fracture stabilization can significantly decrease mortality, musculoskeletal morbidity, and cardiopulmonary and metabolic consequences commonly associated with multiple trauma [58].

Long-bone fractures are a common cause of fat embolism and ARDS. Operative fixation of long-bone fractures in patients with multiple injuries within the first few days of injury can minimize the development of fat embolism [59]. Primary rigid fixation allows the patient to get out of bed and assume an upright position, thus improving pulmonary and musculoskeletal function. Early mobilization, along with the use of mechanical ventilation with PEEP, lowers the incidences of ARDS and remote organ failure [60].

16.4.9 Opioids

The misuse of opioids has led to a public health crisis, and in 2002, opioids became the leading cause of death from unintentional drug overdose in the United States, accounting for more deaths than heroin and cocaine combined. From 2004 to 2008, emergency department visits for the nonmedical use of prescription opioids increased by 111%, which equaled the number of visits for illegal drugs [66]. In 2017 alone, there were 70,237 drug overdose deaths with 47,600 (67.8%) involving opioids, this is a growing crisis, and emergent management of the opioid overdose patient is important [67].

Generally a patient overdosing on opioids will present with severe respiratory depression that can progress to apnea; this is the main life-threatening presentation of opioid overdose. Patients with opioid intoxication present with nausea, vomiting, constipation, miosis, depressed CNS, and respiratory depression (Table 16.8). Patients presenting with an acute opioid

Table 16.8 Opioid intoxication and withdrawal signs and symptoms by organ system

	Opioid intoxication	**Opioid withdrawal**
Central nervous system	Depression of activity	Excitation, restlessness, anxiety, seizures (rare)
	Respiratory depression	Tachypnea
	Increased parasympathetic activity	Adrenergic/sympathetic overdrive (lacrimation, piloerection, yawning, diaphoresis)
Head and neck	Miosis (pinpoint pupils)	Mydriasis
	Antitussive effect	Rhinorrhea
Cardiovascular system	Hypotension to normal blood pressure	Normal blood pressure to hypertension
	Bradycardia to normal heart rate	Normal heart rate to tachycardia
Gastrointestinal tract	Constipation	Diarrhea
	Nausea and vomiting	Nausea and vomiting
Genitourinary tract	Sphincter constriction/spasm	Sphincter relaxation
Musculoskeletal system	Relaxation and flaccidity	Myalgias
Psychiatric manifestations	Euphoria or dysphoria	Drug craving

Adapted from Gutstein and Akil [80]

Table 16.9 Specific opioid toxicities	
Compound	**Toxicity**
Morphine	Acute lung injury
Meperidine	Seizures
Methadone	QTc prolongation, torsades de pointes
Fentanyl	Chest wall rigidity
Propoxyphene	QRS prolongation, seizures
Tramadol	Seizures

Adapted from Gutstein and Akil [80]

overdose should be evaluated for trauma, infection, congestion, electrolyte abnormalities, and complications of prolonged immobility like rhabdomyolysis, compartment syndrome, and mononeuropathies [68]. It is also important to consider that different opioids have distinctive adverse effects (Table 16.9).

The diagnostic tests for an opioid overdose, vital signs, EKG, and chest radiographs, do not guide the treatment because the antidote should be administered before the tests are performed. These tests are to evaluate the possible complications from an acute opioid overdose including arrhythmias, acute lung injury, pulmonary edema, and comorbid diseases. A CBC-diff is to be obtained along with serum creatinine kinase; the CBC-diff is especially important for IV drug users because they get frequent and severe infections. A urine drug screen should also be obtained because opioid can remain in the urine for up to 36 h, but this test is a poor detector for synthetic opioids [68].

Treatment for acute opioid overdose and opioid intoxication begins with evaluation of airway, breathing, and circulation. If the airway is blocked, an oral or nasal airway can be placed, and for apneic patients, a bag-valve-mask ventilation may be required. Naloxone should be administered immediately if opioid intoxication is suspected and can be administered IV for apneic patients with starting doses of 0.4–1 mg and 2 mg for patients in cardiopulmonary arrest [69]. Naloxone can continue to be administered to patients until the desired effect of increased respiration rate is achieved; this increased naloxone demand may be due to the amount of opioid taken or the particular opioid taken. Some opioids such as fentanyl, methadone, and propoxyphene are naloxone-resistant. The naloxone should begin to take effect within minutes and has a duration of action for 20–90 min. If the patient presents with hypotension as an adverse effect, they should be treated with IV fluids and monitored due to possible relapse into respiratory depression. If the patient is presenting with an opioid-induced seizure and the seizure is not responding to the naloxone, then benzodiazepines may be administered. The goal of treatment of opioid withdrawal in the emergency department is stabilization of the cardiopulmonary systems and symptomatic relief. Methadone is the preferred opioid replacement, and missed opioid doses can be replaced with 20 mg orally or 10 mg intramuscularly to reverse withdrawal and avoid overdose. Clonidine has also been shown to reduce blood pressure and diminish withdrawal symptoms [68].

Conclusion

An efficient and systematic assessment of the trauma patient is imperative for timely diagnosis and management of the patient. The more accurately and efficiently this process can be accomplished, the greater the reduction in poor outcomes. There are two phases to the assessment of a trauma patient, the primary survey followed by the secondary survey. The primary survey is an evaluation of the patient's airway, breathing, and circulation and finished with a condensed neurological exam. Survey of these systems gives a proper indication of the patient's vitals and level of consciousness; any abnormality in this survey must be addressed before continuing with the patient assessment. Once the patient's vitals are stabilized, a secondary survey may be performed which includes an abbreviated history of the patient's medical history and their chief complaint and a systematic, objective system-by-system evaluation from head to toe. Evaluating the patient in a systematic approach reduces the chance of error and missed diagnoses. Due to the increasing prevalence of opioid overdose, it is important to include this in the differential diagnosis when evaluating the patient.

Death from traumatic injuries occurs in trimodal time distribution. The initial death peak occurs within seconds to minutes of the injury, and few of these patients can be saved due to the severity of their injuries. The second death peak occurs within a few hours of the injury; this timeframe has often been referred to as the "golden hour" because efficient assessment and management of the patient within this timeframe provides the greatest reduction in risk of death. The third death peak occurs within days to weeks of the initial injury and is most commonly due to sepsis, organ failure, or pulmonary embolism. Injuries can also be classified in three general categories: severe, urgent, and nonurgent. Severe injuries constitute the smallest percent of total injuries but a majority of deaths from injury, and therefore it is imperative to identify these injuries and treat them promptly. Severe injuries will often present during the primary survey because injuries in this category often disrupt the vital physiological process of the body. Urgent injuries do not pose an immediate threat to life but often require surgical correction or repair. Nonurgent injuries constitute the majority of injuries seen, do not pose an immediate threat to life, and require close assessment and observation for any long-term sequelae. In conclusion, initial trauma assessment should be efficient and systematic in order to recognize life-threatening injuries and to provide lifesaving and support measures until definitive care is established.

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