Blunt Thoracic Trauma

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Edward J. Caruana and Sridhar Rathinam

Abstract

Blunt thoracic trauma (BTT) accounts for a significant proportion of chest injuries, which may present in isolation or in the polytrauma patient. There are two well-defined groups of patients who present with BTT:

- Patients with high-energy injuries who tend to have multi-trauma and are critically ill. The aim in managing these patients is to identify life-threatening underlying injuries and stabilise them as much as possible prior to referring to thoracic surgery. Occasionally, the need for urgent surgery by a thoracic surgeon is required, but in most cases minor procedures which can be performed in the prehospital setting and emergency department (ED) will suffice to achieve clinical stability. Specific conditions may require the skills of a specialist cardiothoracic surgeon once clinical stability is achieved.
- Patients with isolated low-energy thoracic trauma with rib fractures and some of the underlying complications. The treatment of these patients tends to concentrate on respiratory support and effective analgesia. In patients with significant fractures and flail segments, early surgical fixation of rib fractures should be performed to achieve better analgesia, faster recovery and prevent prolonged ventilation.

This chapter aims to offer an overview on blunt thoracic trauma and outline practical tips and tricks in the surgical management of blunt thoracic trauma.

E.J. Caruana, M.D., M.R.C.S.Ed. • S. Rathinam, FRCSEd(CSiG), FRCSEd(CTh) (✉)
Department of Thoracic Surgery, Glenfield Hospital, University Hospitals of Leicester NHS Trust, Leicester, UK
e-mail: srathinam@rcsed.ac.uk

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12.1 Introduction: Epidemiology and Outcomes

Thoracic trauma remains one of the leading causes of presentation and mortality in emergency departments (ED) worldwide. Blunt thoracic trauma (BTT) accounts for the majority of cardiothoracic trauma in civilian practice, with the remainder caused by penetrating trauma. BTT can be an isolated injury or part of the polytrauma spectrum [1].

The standard of care provision varies significantly depending on whether the injuries are isolated or associated with other injuries as well as the presence of comorbidities.

1. Major blunt trauma is caused by road traffic collisions (RTCs), work-related accidents, blast injuries in the military setting or civilian terrorism. The treatment of trauma patients is often multidisciplinary in nature, involving emergency physicians, trauma surgeons and specialist care, i.e. neurosurgery, cardiothoracic surgery, general surgery, interventional radiology and intensivists. RTC remains the most common cause of accidental injuries leading to death. Patient mortality due to trauma follows a tri-modal pattern: [2]
   (a) *Immediate* (prehospital) deaths (0–30 min) are responsible for half of RTA deaths, and the causes are often myocardial rupture or thoracic aorta transection along with high spinal and head injury [3].
   (b) *Early* (30 min–3 h) deaths include treatable causes like pneumothorax, cardiac tamponade, airway obstruction and uncontrolled haemorrhage. These conditions if managed promptly and effectively can save lives. Some thoracic interventions in this cohort can be performed in prehospital and in emergency departments improving the outcomes.
   (c) *Delayed* (hours to days) deaths are caused by multi-organ failure and sepsis. The role of dedicated major trauma centres and early access to such specialised centres are essential in improving the outcome of these patients.
2. Isolated BTT with low-energy mechanisms of injury causes rib fractures, flail segments, pneumothorax, haemothorax and lung contusion. The challenge in these patients is the prevention of life-threatening respiratory complications particularly in elderly patients with multiple rib fractures, pre-existing cardiopulmonary disease and limited physiological reserve.

This chapter outlines the basic assessment and management of BTT and offers tips and tricks in surgical interventions and management of blunt thoracic trauma.

12.2 Mechanisms of Trauma

Blunt thoracic trauma results in organ damage by compression, acceleration or deceleration and shear forces often sustained in RTCs, assaults and falls. However, in the elderly, even minor trauma—for example, a fall from standing—can result in serious injury. These mechanisms are usually divided according to the pattern of injury:

- Direct impact from a seat belt or air bag deployment in a RTC which may cause cardiac contusions, pulmonary contusion, sternal or rib fractures (with or without flail segment) and thoracic spine fractures
- Acceleration or deceleration injury—typically caused by a high-energy RTC or a fall from height, resulting in aortic disruption, major airway injury and diaphragmatic rupture
- Crush and asphyxiation injury caused by sudden severe compressive trauma to the chest and abdomen, lasting 2–5 min and often associated with motorcycle accidents

An understanding of specific mechanisms involved in individual trauma patients is crucial because patterns of injury are produced with significant differences in pathophysiology and clinical course, and often life-threatening injuries without obvious external signs are missed.

12.3 Mechanism of Death After Blunt Trauma

The main consequences of BTT are combined respiratory and cardiovascular failure leading to tissue hypoxia and death. This can be caused by:

- Hypovolaemia resulting from major blood loss, with subsequent hypoperfusion and shock
- Ventilation/perfusion mismatch in pulmonary contusion
- Loss of negative intrathoracic pressure such as in tension pneumothorax or open pneumothorax

Immediate deaths from BTT are usually related to cardiac or aortic disruption.

12.4 Tips and Tricks in Diagnosis and Triage

BTT patients should be managed according to the Advanced Trauma Life Support (ATLS) guidelines of assessment and resuscitation [4], which rely on making diagnosis of life-threatening conditions in a systematic way and offer the necessary interventions simultaneously through the primary and secondary surveys.

Primary survey focuses on the ABCDE approach:

- A—airway maintenance and cervical spine control
- B—breathing and ventilation

- C—circulation and haemorrhage control
- D—disability or neurological status
- E—exposure and environmental control

The main injuries to identify include:

- Airway obstruction
- Tension pneumothorax
- Open pneumothorax
- Flail chest and pulmonary contusion
- Massive haemothorax
- Cardiac tamponade

Secondary survey includes a focused history and top-to-toe examination after initial assessment and treatment of life-threatening injuries. When assessing chest injuries, the mechanism of trauma is invaluable in terms of immediate injury management and eventual outcome. Diagnosis is reliant on accurate history from pre-hospital teams in order to tailor the clinical assessment and investigations to identify and exclude various injuries.

Relevant information like speed of collision, position of colliding vehicles, position of patient in the car, use of seatbelt and extent of vehicle damage (intrusion, windscreen damage, difficulty and length of extrication, air bag deployment) help in diagnosis.

Likewise for falls from a height, height of fall, objects struck (banisters or scaffolding), landing surface, part of body injured and reason of fall (industrial, drugs or alcohol, epilepsy) are all relevant in management decisions [5].

12.5 Tips and Tricks in Imaging

12.5.1 Chest Radiograph

Chest radiography (CXR) is the most frequently performed first-line investigation in thoracic trauma as it can be performed in the resuscitation area whilst actively managing critical patients. Although it offers limited information, it helps in diagnosis and guides further imaging. Injuries to the first two ribs indicate high-velocity trauma and warrant a computed tomography (CT) of the thorax to rule out vascular injuries. Fractures to the lower four ribs are commonly associated with injuries to the abdominal organs which warrants an ultrasound scan or a CT of the abdomen.

A widened mediastinum should lead to suspicion of aortic injury, and a globular heart shadow may indicate the possibility of a pericardial collection. CXR also reveals features suggestive of aortic transection including loss of the aortic knob, displacement of the nasogastric tube to the right of the T4 spinous process, left apical pleural cap, widened paraspinal lines, widened right paratracheal stripe greater than 5 mm and loss of the descending aortic line, although these are not pathognomonic of aortic transection and the only diagnostic sign of aortic rupture is a widened mediastinum >8 cm at the aortic knob [6].

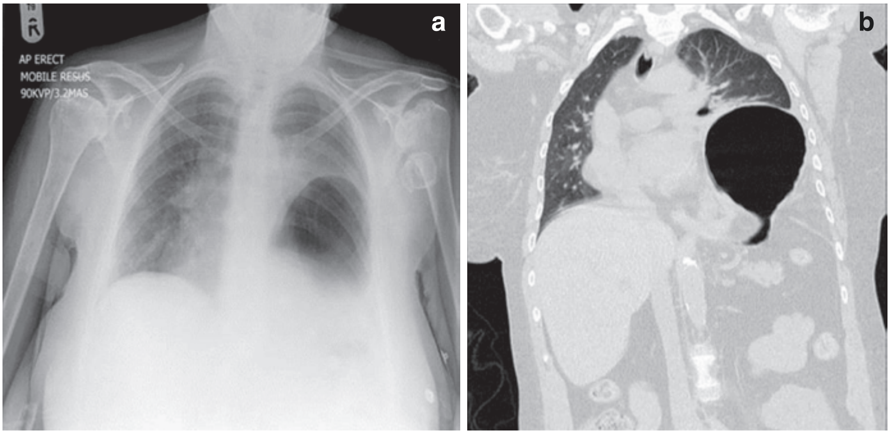

Fig. 12.1 Chest radiograph and CT scan demonstrating diaphragmatic rupture

The presence of pneumomediastinum indicates possible oesophageal perforation or tracheobronchial injury, whilst in diaphragmatic injury, bowel gas shadows may be seen in the chest (Fig. 12.1). Tracheobronchial disruption is confirmed by the 'fallen lung' sign, pneumothorax with the hilum of the collapsed lung situated lower than the normal hilar position. These features need further evaluation with appropriate further imaging.

12.5.2 Computed Tomography (CT)

CT in haemodynamically unstable polytrauma patients has become an integral part of the management of multi-trauma patients. Although once discouraged and historically referred to as 'the doughnut of death', the speed and the quality of this modality offer a wealth of information with regard to the skeletal injuries, pleural collections underlying pulmonary status as well as mediastinal structures. Recent reconstructed CTs offer better visualisation of rib fractures, flail segments and diaphragmatic injuries (Fig. 12.1b). The use of CT does not increase the mortality of haemodynamically unstable patients; meanwhile it prevented unnecessary surgery [7]. Results of the REACT-2 randomised controlled trial which investigated the role of total-body CT scanning compared to those by the 'standard work-up' with selective CT scanning have shown no survival benefit and only modest improvement in detecting relevant incidental findings. The use of routine CT scan to screen for aortic injury will remain debatable as aortography is the gold standard in aortic injuries. CT has the advantages as it may reveal other unsuspected intrathoracic injuries; a negative scan obviates the need for aortography, which carries a combined morbidity and mortality of 1.7% and is a costly investigation. However, the disadvantages are a positive scan merely delays the definitive aortogram and surgery. Helical CT has a sensitivity of 95% for detection of aortic injuries, but a specificity of 40%, rate requiring further investigation, and finally there are differences in defining the criteria for aortic injury [8].

12.5.3 Electrocardiogram

Twelve-lead electrocardiogram (ECG) reveals non-specific ST- and T-wave changes, sinus tachycardia, supraventricular tachycardia and conduction abnormalities which may progress to complete heart block as oedema develops around the conducting tissues in myocardial contusion.

12.5.4 Focused Abdominal Sonography for Trauma (FAST)

FAST is a portable, non-invasive test which can be readily performed in 3 min and has become an integral part of trauma evaluation, primarily to assess for pericardial tamponade haemopneumothorax and injuries to the intrathoracic abdomen [9].

12.5.5 Aortography

Aortography is the investigation of choice for suspected aortic transection. False positive may occur with ductal bump or a previous aneurysm but can be excluded by a CT showing the absence of a mediastinal haematoma. The sensitivity of aortography is 73–100% with a specificity of 99% [10].

12.6 Tips and Tricks in Managing Life-Threatening Presentations

There are a variety of conditions which manifest at the scene of injury to the definitive care centre which can be managed by prehospital care clinicians and emergency department clinicians. However there are specific areas where the expertise of a thoracic surgeon is invaluable (Table 12.1).

12.6.1 Airway Compromise

Blood, teeth, dentures and debris can cause obstruction of airways; the blockages must be relieved and patency maintained with basic life support manoeuvres and employment of appropriate airway adjuncts. The compromised, injured airway should be managed with immediate placement of an endotracheal tube distal to the site of injury. If the injury to the trachea is proximal or there are associated maxillofacial injuries, there is a need for cricothyroidotomy. Distal tracheobronchial disruption demands immediate anaesthetic intervention requiring double-lumen intubation.

12.6.2 Cricothyroidotomy

Transtracheal ventilation may be achieved in an emergency setting by passing a tube through the cricothyroid membrane—a palpable depression just above the cricoid

Table 12.1 Input from cardiothoracic surgeons [5]

	Mechanism	Investigations	Management
Massive air-leak	Parenchymal laceration, Tracheobronchial injury	Chest X Ray CT Diagnostic chest drain	Thoracoscopic assessment Staple laceration
Tracheobronchial injury	Right more common than left due to weight of lung and unprotected right main bronchus.	Fallen lung sign Chest X Ray CT Chest	
Aortic transection	Osseus pinch or Bell clanger effect in rapid deceleration.	Contrast CT Aortogram	Clamp and sew or definitive repair on bypass
Cardiac rupture	Sudden deceleration and compression by sternum	Clinical deterioration FAST	Repair of chambers to stop bleeding definitive repair under Cardiopulmonary bypass with Transoesophaeal echo guidance
Flail segments	Multiple site fractures. Causing paradoxical movement Significant pain	Chest X Ray CT with reconstruction	Clinical decision making Rib fixation using adjuncts
Massive/clotted haemothorax	Common causes are bleeding from adhesions, intercostal vessels, internal mammary artery. Rarely hilar, parenchymal and heart bleed.	Chest X Ray Clinical examination CT Chest	Thoracoscipic evaluation if patient stable. Hilar control if ongoing bleeding Evacuation of clots with haemostasis by diathermy, suturing vessels or packing
Diaphragmatic rupture	Left more common than right. Sudden pressure changes Consider risk of rupture of abdominal contents in the pleura.	Chest X Ray (with NG tube) CT Chest	Thoracoscopic assessment and repair Thoracotomy and primary closure or use buttress material
Oesophageal rupture	Fall, RTA	Chest X Ray Oral contrast CT Gastrograffin swallow	Repair with muscle flap cover Diversion with chest drainage

cartilaginous prominence—in the midline [11]. Slight extension of the neck, with manual stabilisation of the thyroid cartilage, facilitates identification and instrumentation.

There is an insufficient evidence base to demonstrate the superiority of any of the various surgical and percutaneous techniques described in the literature [12]. Surgical insertion is thought to be safer than a percutaneous approach in inexperienced hands [13].

12.6.3 Needle Cricothyroidotomy

A large-bore (14 gauge or larger) intravenous cannula may be used for needle cricothyroidotomy, in the absence of dedicated equipment.

Following appropriate skin preparation, a needle-mounted catheter on a syringe half-filled with water is advanced through the cricothyroid membrane in its midline directed caudally at 45°, whilst maintaining negative pressure on the plunger. Easy flow of air confirms entry into the airway, at which point the catheter should be advanced over the needle to its hilt.

Oxygenation may be achieved by attaching high-flow (15Lpm) oxygen to the catheter via a three-way tap open to air. Cyclical intermittent occlusion (1 s) and release (3 s) of the side limb of the three-way tap allows oxygenation and some degree of ventilation, as a temporising measure to a more definitive airway.

12.6.4 Percutaneous Cricothyroidotomy

A standard Seldinger technique may be adopted, using purpose-made commercially available kits.

Following cannulation of the airway as described for needle cricothyroidotomy above, the guidewire is threaded into place and the cannula removed. A small skin incision is performed and tract dilatation and airway catheter insertion performed either simultaneously or successively, depending on the equipment in use, prior to securing in place.

12.6.5 Surgical Cricothyroidotomy

Emergency surgical cricothyroidotomy may be performed using a scalpel, curved blunt dissection forceps (e.g. Kelley), gum-elastic bougie and a small (size 6) endotracheal or tracheostomy tube.

Following skin preparation and identification of landmarks, a 2 cm horizontal incision is made through the skin and soft tissues above the cricothyroid membrane. A horizontal stab incision is made into the cricothyroid membrane using the scalpel (whilst taking care not to injure the back wall of the airway). This is then dilated using blunt dissection forceps and a gum-elastic bougie inserted into the trachea. The appropriate-size tube is then positioned over the bougie and secured.

12.6.6 Tension Pneumothorax

Injury to the visceral pleura or upper airway can result in rapid accumulation of air in the pleural space and collapse of the lung. A flap laceration of the lung parenchyma may create a one-way valve, causing intrapleural pressure to rise and mediastinal structures to be compressed. The venous return to the heart is thus compromised. The classic symptoms and signs are chest pain, air hunger, respiratory distress, tachycardia, hypotension, tracheal deviation to the contralateral side, hyper-resonance on percussion, unilateral absence of breath sounds and neck vein distension.

The diagnosis of this condition is clinical, not radiological. Immediate needle thoracocentesis through the second intercostal space in the mid-clavicular line converts the tension pneumothorax into a simple pneumothorax, which subsequently should be treated with chest drain insertion. If tension pneumothorax occurs on both sides, unilateral signs may be absent. Bilateral needle thoracocentesis or thoracostomy followed by bilateral chest drain insertion is required.

12.6.7 Thoracostomy

Chest drainage [14] may be achieved safely in an emergent scenario, at either of the following sites.

The ‘safe triangle’ is defined anteriorly by the lateral border of pectoralis major (anterior axillary line), posteriorly by the mid-axillary line (classically by the anterior border of latissimus dorsi—that is, the posterior axillary line; however, this places the long thoracic nerve of Bell at risk during insertion) and inferiorly by the nipple line. Inadvertent low chest tube siting is common [15].

An anterior thoracostomy may be placed in the second or third intercostal spaces, at or just lateral to the mid-clavicular line. Care should be taken to avoid instrumenting superiorly at this site, to minimise the risk of subclavian vascular injury and to be mindful that medial insertion places the internal mammary vessels at risk.

Consider the positioning of the intercostal bundle just inferior to the ribs. Intercostal dissection and tube insertion should skim just above the lower rib, so as to minimise bleeding and pain complications.

Where possible, avoid insertion at sites of known rib fractures or external injury. Bedside image guidance in the form of ultrasound may guide the competent user to target other sites but should only be used in the stable patient.

Patients are classically positioned semi-recumbent at a 45-degree angle. The arm should be abducted and externally rotated (placing the hand above and behind the patient’s head) to facilitate insertion into the safety triangle. In unstable patients, the supine position may be used, with abduction or extension of the arm facilitating lateral insertion.

12.6.8 Needle Thoracocentesis

A long, large-bore needle-mounted catheter is inserted into the pleural space either anteriorly or laterally in the safe sites described above [16] and the needle then removed to leave the soft catheter in situ. Initial success rates are low, with an even higher incidence of early failure due to catheter kinking or displacement [17].

The use of longer, dedicated pleural thoracocentesis needles may increase the success and longevity of this intervention [18]. Repeated instrumentations (placed progressively lateral to the mid-clavicular line) may be attempted to temporise, if necessary. Custom-made decompression needles offer the benefit of inbuilt one-way valves which aid rapid decompression (Fig. 12.2a) [19].

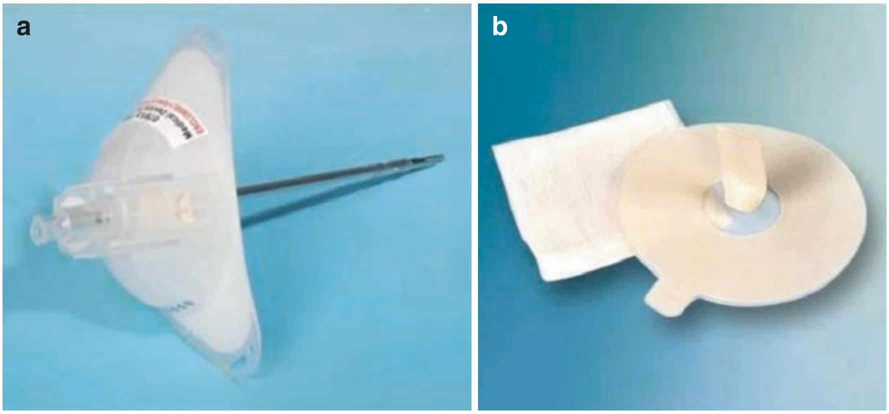

Fig. 12.2 (**a**) ThoraQuik needle decompression device. (**b**) Asherman Chest Seal

Nonetheless, needle thoracocentesis is a decompressive intervention and not a definitive pleural drainage system, which thus should be succeeded by tube thoracostomy [20].

12.6.9 Open Thoracostomy

An ‘open’ or ‘finger’ thoracostomy may be used to achieve decompression of the pleural space, quickly draining both blood and air. A scalpel and curved blunt dissection forceps are sufficient equipment for this purpose. Bilateral open thoracostomy may only be performed in patients receiving positive-pressure ventilation.

Following skin preparation with an antiseptic solution, generous infiltration of local anaesthetic (20 mL of 1% Lignocaine) through the tissues (particularly to the skin and parietal pleura) should precede insertion in the awake patient.

A generous (at least 3 cm), full-thickness incision is made through the skin and subcutaneous tissues, along the direction of the ribs. Blunt dissection (Roberts or Kelly) forceps are used to dissect a tract through the chest wall and intercostal musculature just at the upper border of the rib, with intermittent finger palpation to confirm positioning. Dissect one single tunnel perpendicular to the chest wall, avoiding long or multiple blind subcutaneous tracts that may complicate insertion. The closed dissection forceps should be used to puncture the pleura in a controlled fashion; opening the dissection forceps prior to extracting from the chest will dilate the pleural defect and tract through the chest wall.

A finger should be inserted into the pleural space and swept circumferentially along the inside of the chest wall, to confirm safe entry to the pleural space and sweep away any loosely adherent lung. Failure to digitally confirm safe entry and sufficient intrapleural space may demand re-attempting insertion at an alternate site.

Note that soft tissue may reappose to occlude the thoracostomy, requiring repeated digital or blunt dissection. Patient and equipment positioning may also occlude the thoracostomy site. Open thoracostomy may be considered an interim in the prehospital or trauma resuscitation setting but should be converted to a tube thoracostomy once appropriate.

12.6.10 Tube Thoracostomy

A large-bore—at least 28Fr—chest tube should be mounted on the dissecting forceps, just proximal to its tip, and inserted through the tract formed as described above [21].

Ensure that all chest tube fenestrations are located well within the pleural cavity, adjusting for variable subcutaneous tissue depth in different patients. The tube should generally be oriented apically when attempting to drain air and basally for fluid. Clamping of the tube until it is connected to a drainage system may reduce soiling, particularly when draining fluid.

Once positioned, the chest tube should be connected to an underwater seal and secured using a heavy, braided suture.

Tube placement should be confirmed by plain film imaging, once the clinical situation allows.

12.6.11 Open Pneumothorax

This results from an opening through the chest wall into the pleural cavity. If the opening exceeds two thirds of the diameter of the trachea, preferential air flow through the defect prevents generation of the negative intrapleural pressure required to expand the lung. The initial management consists of covering the defect to create a one-way valve to evacuate the air in the pleura. This can be done with an Asherman Chest Seal (Fig. 12.2b) or, if this is not available, a dressing plastered on three sides. As soon as possible, a chest drain should be placed, remote from the wound.

12.6.12 Massive Haemothorax

Massive haemothorax may occur with accumulation of 1500 mL of blood in the pleural cavity with resulting hypovolaemia and hypotension. Management consists of replacement of circulating volume and decompression of the chest with large chest drains (>28 FG). Immediate drainage of 1500 mL of blood may need urgent thoracotomy and definitive haemostasis [22]. If initial drainage is less than 1500 mL, there may still be a need for a thoracotomy if blood loss exceeds 200 mL/h over the next few hours. Pending this decision, the patient must be closely monitored in a high-dependency setting.

12.6.13 Cardiac Tamponade

Although cardiac tamponade is associated more with penetrating trauma, it is not uncommon to have it in blunt trauma. This can be caused by rib fractures causing pericardial or myocardial laceration and missile injuries in RTC caused by debris as well as myocardial rupture.

12.7 Tips and Tricks in Emergency Access

12.7.1 Thoracotomy and Thoracosternotomy

The patient should be sedated, paralysed and intubated prior to commencing the procedure. Double-lumen intubation or the use of a bronchial blocker may be used to achieve selective lung isolation; however, this is technically challenging and often time-consuming. A single-lumen tube with brief periods of apnoea may be undertaken to facilitate vision or intervention, if required. The left lung may additionally be isolated by selectively advancing a single-lumen tube down to the right main bronchus [23].

The patient should be supine, with the arms secured in a flexed position above the patient's head (where practical).

A scalpel, dissection scissors and rib spreader (e.g. Finochietto) and heavy trauma shears are sufficient for the purposes of accessing the chest.

Note the risk of profuse bleeding from chest wall and internal mammary vessels that are at risk of iatrogenic injury during emergency access to the thoracic cavity. This typically occurs with return of spontaneous circulation and should be actively sought and stemmed.

12.7.2 Anterior Thoracotomy

The anterior thoracotomy is preferred for access to the traumatised chest in clinical instability. A left-sided approach is adopted in all patients in cardiac arrest, to allow internal cardiac massage. Right-sided thoracotomy is indicated in patients with a spontaneous circulation and right-sided trauma.

Following appropriate (bilateral) skin preparation, a curved submammary incision through the skin, subcutaneous tissue and muscle (anterior border of latissimus dorsi) is performed extending from the sternal border to the mid-axillary line (Fig. 12.3a).

The chest is then entered bluntly using dissecting forceps (Roberts) in the fourth intercostal space (just above the fifth rib, avoiding injury to the intercostal bundle), with a finger then inserted to retract the lung away whilst transecting the intercostal

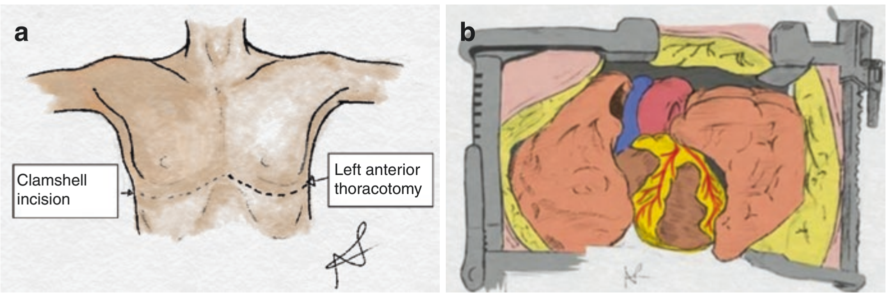

Fig. 12.3 (**a**) Anterolateral thoracotomy and clamshell incision. (**b**) Clamshell incision with exposed thoracic cavity

muscles along the length of the incision with scissors. A brief period of apnoea with ventilator disconnection allows the lung to collapse once the pleura is breached, reducing the risk of iatrogenic injury.

Improved access may be achieved by extending the incision across the contralateral sternal edge and horizontally splitting the sternum using heavy shears or a saw (e.g. Gigli) and/or by cutting the fifth rib posteriorly.

12.7.3 Thoracosternotomy

Where access to both sides of the chest is required, bilateral anterior thoracotomies may be performed and joined by a horizontal sternal division to give a ‘clamshell’ incision. The use of rib retractors bilaterally (or a single retractor placed at the sternum) will lift the upper chest, providing excellent access (Fig. 12.3b).

12.8 Tips and Tricks in Managing Injuries Associated with Blunt Trauma

12.8.1 Rib Fractures

The true incidence of rib fractures is not known, as 50% may not be apparent on a chest radiograph [24]. Patients rarely present with isolated rib fractures; the majority have associated intrathoracic injuries, and of particular significance are fractures of the first rib. These are uncommon injuries because of the first rib’s rigid structure and relatively protected location. They are indicative of severe trauma and should prompt a search for associated visceral injury.

12.8.2 Flail Chest

Flail chest occurs where a portion of the chest wall is free floating due to multiple segmental rib fractures and occurs in about 5% of thoracic trauma patients. The ensuing pulmonary insufficiency results from three pathophysiological processes:

1. A negative intrapleural pressure cannot be maintained due to the paradoxical motion of the flail segment.
2. Pulmonary contusions sustained at the time of the injury cause haemorrhage and oedema of the lung underlying the flail.
3. Severe pain associated with the multiple fractured ribs results in hypoventilation.

The inadequacy of the resulting ventilation is indicated by arterial blood gas analysis. Treatment consists of appropriate analgesia to enable more effective chest wall movement, with ventilatory support if appropriate. Early fixation should be considered in these patients with respiratory compromise to prevent prolonged ventilation [25]. This can be done by using Stratos clasping device which stabilises the fracture and holds them together or Synthes plates and screws.

12.8.2.1 Rib Fixation

The access is approached through a lateral thoracotomy with individual surgeon preference varying between vertical axillary incision or lateral thoracotomy-like skin incision. The latissimus dorsi muscle fibres are divided to expose the serratus anterior. The serratus aponeurosis is divided to expose the ribs. The sites of fractures are identified. The periosteum is cleared to delineate the ribs; the ribs are stabilised with the stabilisers. The choice of the adjuncts varies between surgeons and is also dictated by the underlying ribs.

The Synthes system uses plates and screws; hence, healthy bones are a requirement as osteoporotic bones may disintegrate when the screws are fitted. Healthy bones need to be measured with the calipers to define the rib height. This allows selection of the correct size of screws. It is advisable to place three screws on each side of the fracture. It will be necessary to drill the holes prior to placing the self-locking screws. There are different plates which are in keeping with the size of the ribs; alternatively there are small plates as well. It is not necessary to fix every fracture, and usually fixing alternate ribs offers enough stability and relieves pain (Fig. 12.4a).

The Stratos system uses clasped adjuncts which wrap around the fractures to offer stability; care is taken to avoid the intercostal bundle whilst placing these adjuncts. If there are multiple fractures, there are long rods which allow interlinking the claspers (Fig. 12.4b).

12.8.3 Cardiac Tamponade

Although this is more common in penetrating trauma, blunt chest injury may also result in rupture of a cardiac chamber and subsequent tamponade. Injury to the heart or pericardial vessels causes blood to accumulate within the pericardial cavity. Increased intra-pericardial pressure acting on the low pressure atria and venae cavae reduces venous return, with consequent haemodynamic instability, manifesting

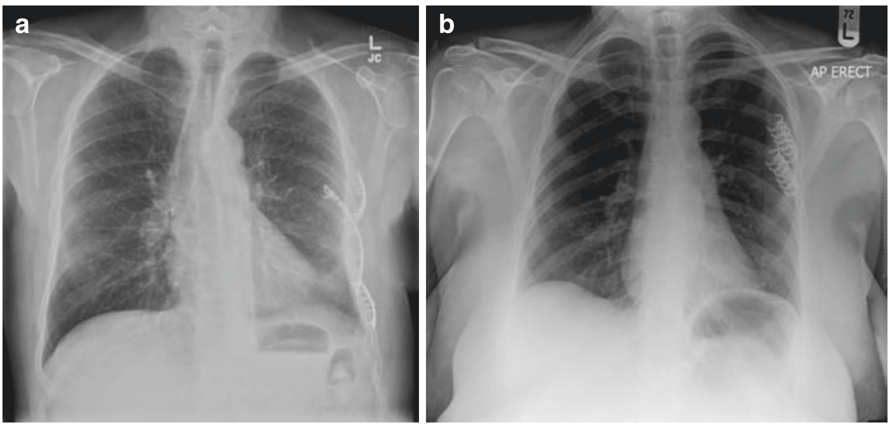

Fig. 12.4 (**a**) Rib fixation with plates and screw (Synthes). (**b**) Rib fixation with plates and screw (Stratos)

clinically as Beck's triad of increased jugular venous distension, hypotension and muffled heart sounds. Management consists of immediate surgical drainage and vascular repair. The condition may be temporarily relieved by the creation of a subxyphoid window, through which the pericardial cavity can be opened. Fluid resuscitation and needle pericardiocentesis have been shown to be of limited benefit [26].

12.8.4 Sternal Fractures

Sixty-six percent of traumatic sternal fractures is the result of an impact with a steering wheel. Wojcik and Morgan [27] report the incidence of associated cardiac contusion at 6%. Patients do not usually require inotropic support or develop dysrhythmias, and these injuries are managed conservatively. However, if the sternum is unstable, there are adjuncts which can be used to fix sternal fractures.

12.8.5 Pulmonary Injuries

Blunt trauma is more commonly associated with lung contusion, but if there are rib fractures caused by a blunt mechanism, pulmonary lacerations and pneumothoraces can ensue.

Blunt contusion of the lung can lead to sequestration of blood. In the absence of active bleeding, if the patient requires, volume contusion has to be born in mind as this can lead to volume loss. Another complication of blunt trauma is pulmonary haematoma. Although it is difficult to distinguish in the initial imaging, delayed films will demonstrate the haematoma as a more circumscribed area.

Most lacerations and air leaks may stop with chest drainage and conservative management. However if there is persistent air leak, surgical intervention may be warranted. Mostly surgical intervention in this cohort is performed as a planned procedure with the patient stable.

The choice of thoracoscopic or open approach is dictated by the stability of the patient to tolerate single-lung ventilation and surgeon's expertise.

12.8.6 Laceration

Lacerations are identified and are sutured with absorbable sutures. Alternatively, the laceration can be excluded and excised with a firing of stapler. The use of glues and adjuncts is best avoided as there is an increased risk of infection.

12.8.7 Tractotomy

A traversing injury has to be laid opened and explored (tractotomy), and major vessels and bronchi should be oversewn or repaired. This can be done by passing a pair of forceps and cutting it open or using a linear cutting surgical stapler, placing the anvil in the track and the staple cartilage on the lung surface. This lays the track open whilst sealing the edges.

12.8.8 Lung Resection

Repair of damage to major vessels in the hilum may require hilar control with clamps and sometimes may necessitate opening the pericardium. Sometimes the only option may be a lobectomy if there is destruction of the lobe with the missiles or glass pieces although the morbidity and mortality are very high.

12.8.9 Blunt Cardiac Trauma

The incidence of myocardial injury in victims of blunt chest trauma is 15–75%; however, a high index of suspicion is necessary, as myocardial injury often occurs in the absence of external signs. Blunt injury to the heart is almost always secondary to rapid deceleration in RTA when deceleration causes the heart to be crushed between the sternum and the spine. Primary crush accidents or a direct injury to the anterior chest wall will cause the same injuries.

Blunt cardiac injury causes disruption of the valvular apparatus, myocardial contusion or cardiac chamber rupture. ECG findings are variable, and measurement of the creatine kinase MB isoenzyme has been shown to be a sensitive marker of myocardial damage with a rise of greater than 6% of total CK-MB which is predictive of subsequent myocardial events. Elevated troponin I correlates with ECG changes and is indicative of myocardial damage. Echocardiography is very useful in assessing the contused myocardium.

12.8.10 Aortic Transection

Blunt rupture of the thoracic aorta is most commonly associated with rapid deceleration during RTC. This is caused by two mechanisms: (1) the *osseous pinch* effect where the deceleration or impact pushes the sternum backwards towards the vertebral column and the aorta is pinched between the two and (2) the *bell clanger effect* where the blood in the aorta pulls forwards like a bell clanger against the aorta which is fixed at the level of the isthmus. The majority of these patients die at the scene, and less than 25% survive to reach the hospital. The patient usually presents with a history of a blunt deceleration injury. Clinical presentation of the aortic injury is usually non-specific, with 20–50% of patients shocked and dyspnoeic. 30–50% of patients complain of interscapular or retrosternal pain. Reduced blood pressure in the arms compared to the legs is present in 7–40% of patients and is highly suggestive of acute aortic transaction. The strategies of management of aortic injuries are beyond the scope of this chapter; however, the principles are clamp and sew technique or repair under partial or complete cardiopulmonary bypass.

12.8.11 Diaphragmatic Injuries

Blunt trauma can cause diaphragmatic rupture due to sudden pressure changes; this is more common on the left side as the right is buttressed by the liver. Current CT scanners can identify diaphragmatic tears and ruptures (Fig. 12.1a, b). However the definitive diagnostic tool still remains a thoracoscopic examination as it allows clearance of the haemothorax, assessing the diaphragm as well as repairing it. The repair depends on the size of the rupture which can be closed primarily with non-absorbable sutures and if large buttressed with a mesh. A missed diaphragmatic injury may manifest later as herniation of abdominal contents more in the left than in the right. This may lead to intrathoracic obstruction or perforation with life-threatening consequences.

12.8.12 Tracheobronchial Injuries

The incidence of tracheobronchial injuries is between 0.85 and 2.8% in patients with blunt trauma, though many suffering major airway injury will die at the scene of the accident. Tracheal injuries can occur in deceleration RTA when the extended neck strikes the dashboard or steering wheel, crushing the trachea against the vertebral bodies. Tracheobronchial disruption is more common in the right side as the right main bronchus is unprotected unlike the left which is enclosed between the aorta and pulmonary artery and the weight of the right lung is more than the left.

12.8.13 Oesophageal Injury

Primary injury to the oesophagus is very rare in BTT due to its deep position within the mediastinum. However, it may occur as a secondary phenomenon caused by barotrauma. If there is blunt rupture of the oesophagus, primary repair with buttress done rapidly offers the best outcomes; however, if there is delay and soiling, diversion and chest drainage will stabilise the patient to enable transfer to a specialist centre.

12.9 Post-injury Care and Management

It is important to highlight the value of chest physiotherapy, analgesia and serial observation and imaging. Chest trauma victims can change their clinical stability very rapidly; hence, intense monitoring is mandatory. Pain management particularly if there are multiple ribs fractured or flail segments is provided with patient-controlled analgesia, intercostal blocks and epidural. A good regime of exercise, mobilisation and breathing exercise is vital in preventing pulmonary collapse and superadded infection especially in frail elderly patients. It is important to nurse elderly patients with input from elderly care physicians to address their comorbidity whilst treating with the thoracic trauma. Finally, they need a delayed imaging to rule out any delayed haemopneumothoraces both from a clinical and medicolegal perspective.

12.10 Delayed Presentations and Complications of Thoracic Trauma

Patients may re-present, or present late, with delayed complications resulting from blunt thoracic trauma. These commonly include retained, delayed or recurrent haemothorax, which may become secondarily infected resulting in pleural empyema in a quarter of patients [28] and occult diaphragmatic injury that may present with late dyspnoea as a result of paralysis or herniation of abdominal contents [29].

12.11 Role of Video-Assisted Thoracoscopic Surgery (VATS) in Thoracic Trauma

Minimally invasive surgery may be an appropriate initial approach in selected patients. It offers the advantage of better visualisation in hard-to-reach areas, whilst minimising the additional physiological insult associated with any surgical intervention. One should note both the diagnostic and therapeutic value of this approach [30].

Successful VATS without significant morbidity has been described in acute bleeding (with successful haemostasis), retained haemothorax and post-traumatic empyema (with adequate clearance and satisfactory lung expansion), diaphragmatic injuries (with definitive repair) and persistent air leak (with endoscopic control by means of repair and parenchymal resection) [31]. Rib fracture fixation may be performed by means of a VATS-assisted approach. Conversion thoracotomy is reported in circa 10–20% of cases [32, 33]. Early VATS intervention may also reduce lengths of hospital stay and associated costs in this patient group [34, 35].

Conventional VATS port positioning may be adopted, whilst being mindful of associated localised soft tissue and bony injury at potential access sites, as well as of the increased potential for visceral damage in the presence of altered anatomy.

Conclusion

Civilian blunt trauma is a common problem faced by most emergency units. The trauma network and good prehospital care have resulted in channelling these patients to appropriate units. Most thoracic traumas are best managed with resuscitation and chest drains; however, the analgesia, antibiotics and chest physiotherapy have invaluable role to play in the ultimate outcome. Resuscitative and emergency thoracotomies are still invaluable skill set for clinicians involved in the care of trauma patients as these procedures save lives. Appropriate referral to specialist centres and follow-up are essential to avoid delayed complications.

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