Chapter 6
Surgical Treatment of Thoracic Trauma: Lung

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6.1 Introduction

The vast majority of traumatic pulmonary injuries can be treated nonoperatively or with tube thoracostomy alone. The main indications for operative intervention are hemorrhage or large airway injury. Major pulmonary hemorrhage is most commonly caused by penetrating mechanisms, while large airway injury may result from blunt or penetrating mechanisms. Lung injuries may also be found at the time of thoracotomy performed primarily for management of other injuries. This chapter discusses the indications for surgical management of lung injuries, describes techniques for obtaining vascular control and addressing parenchymal and airway injuries, and explains basic considerations in postoperative care.

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6.2 Initial Evaluation and Indications for Surgery

Patients with lung trauma require the same measures for initial stabilization as other trauma patients including airway control and a thorough evaluation for other injuries. This is not discussed at length here. Although there are some considerations for airway injury discussed below, the primary means or airway management remains rapid-sequence orotracheal intubation with a single-lumen endotracheal tube in patients who cannot oxygenate or ventilate adequately on their own. Other chapters on neck and mediastinal trauma discuss special considerations in tracheal or upper airway injury.

All patients with chest injury should be evaluated for hemothorax or pneumothorax. Essentially all patients with operative lung injuries will present with one or both of these findings. This assessment can be made in the trauma bay with chest X-ray or, if the clinician is adequately experienced, with ultrasound as part of the extended focused abdominal sonography for trauma (E-FAST) exam. In unstable patients with signs of chest injury on physical exam, urgent tube thoracostomy can be both diagnostic and therapeutic and should not be delayed to perform imaging. Whether performed before or after imaging, all patients with significant pneumothoraces or hemothoraces after trauma should undergo tube thoracostomy (Fig. 6.1). Even for urgent tube thoracostomy, correct sterile technique with wide draping and gown, glove, and mask use can almost always be adhered to. Additionally, we recommend a single periprocedural dose of antibiotics.

The primary indications for thoracotomy in patients with suspected lung injury are major bleeding or major airway disruption. Immediate drainage of over 1,500 mL of blood or greater than 200 mL of blood per hour for 4 h after tube thoracostomy is

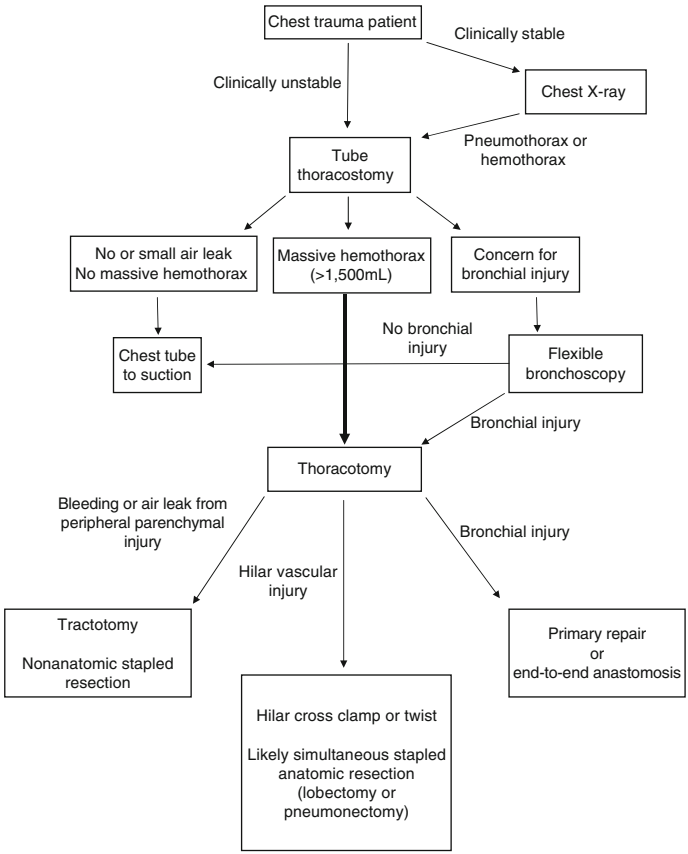

Fig. 6.1 Algorithm for the initial management of lung trauma

an indication for thoracotomy in the case of bleeding, as this degree of hemorrhage is unlikely to resolve without surgical intervention. No further preoperative evaluation is needed (Fig. 6.1).

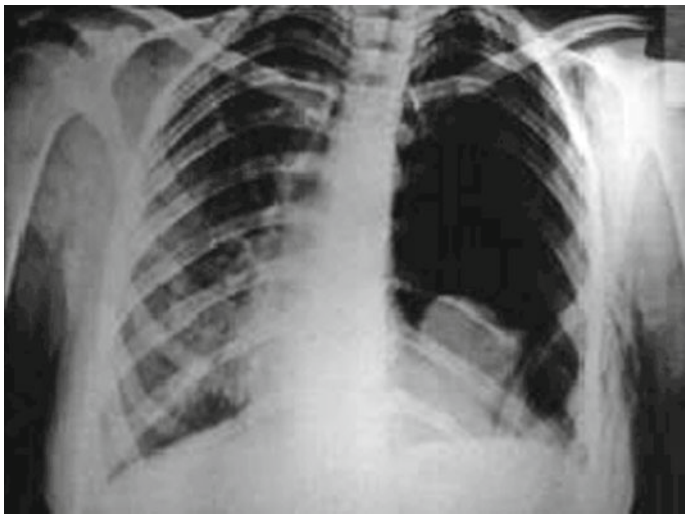

Fig. 6.2 Chest X-ray showing a "fallen lung" suggesting a major bronchial injury

In the case of major airway injury, persistent pneumothorax despite adequate chest tube placement, a blowing air leak, loss of tidal volumes in mechanically ventilated patients, or a "fallen lung" or pneumomediastinum on chest X-ray are signs of major airway injury (Fig. 6.2). Occasionally, placing a chest tube to suction under these conditions will worsen the clinical situation, as it can evacuate the entire tidal volume and interfere with ventilation of the uninjured lung. If this occurs, the tube should be placed to water seal. Flexible bronchoscopy remains the standard for diagnosis of large airway injury – it allows identification of the site of injury and is the most sensitive means of excluding airway injury when the clinical picture is not clear. While standard chest computed tomography (CT) may demonstrate a site of airway injury and is useful to

evaluate for associated injuries, it is not sensitive and cannot reliably exclude airway injury.

In the absence of these signs of major bleeding or airway disruption, tube thoracostomy alone suffices for treatment of pneumothorax or hemothorax. This is the case in over 90 % of traumatic lung injuries.

6.3 Operative Preparation and Choice of Incision

For patients in whom injury can be confidently isolated to one hemithorax and who are stable enough to allow for positioning, a posterolateral thoracotomy through the fifth intercostal space with the patient in the lateral decubitus position provides the best exposure for surgical treatment of pulmonary injuries as it allows all surfaces of the lung to be exposed and allows anterior and posterior exposure of the pulmonary hilum. However, victims of both blunt and penetrating lung trauma are at high risk for extrathoracic injuries that may require simultaneous management, and these considerations will necessarily influence the approach to the thoracic injury. For example, a patient requiring a simultaneous laparotomy will need to be placed supine, making a lateral or posterolateral thoracotomy impossible. Many pulmonary injuries can be definitively managed or at least damage controlled through an anterolateral thoracotomy. Occasionally these patients may need to be repositioned after extrathoracic injuries have been addressed to allow definitive repair of their thoracic injuries.

A double-lumen endotracheal tube is not necessary for the majority of lung trauma cases, but a contralateral double-lumen tube is especially useful, if possible, for cases of suspected or confirmed main stem or lobar bronchial injury.

6.4 Techniques for Hemorrhage Control

Thoracic exploration for hemorrhage is most often performed on the basis of hemorrhage from a thoracostomy tube. The site of bleeding is seldom localized preoperatively. A thorough exploration must be performed. Techniques for addressing major vascular injuries (such as cardiac, aortic, or great vessel injury) are described elsewhere in this book. Bleeding from chest wall sources – usually either an intercostal artery or the internal mammary artery – can be controlled by ligation.

Hemorrhage from the lung should be categorized into hemorrhage from the peripheral pulmonary parenchyma and hemorrhage originating from the proximal parenchyma or hilum. Most injuries involve the peripheral parenchyma. The two most effective techniques for dealing with bleeding pulmonary parenchyma are stapled nonanatomic pulmonary resection and pulmonary tractotomy with direct ligation of bleeding vessels (Fig. 6.3). These are the most important techniques in the management of operative lung trauma. A 100 mm long linear cutting stapler with 3.8 mm staples is preferred for both of these techniques. When staple lines must cross thicker, more central parenchyma, a linear stapler with thicker 4.8 mm staples may be used. Nonanatomic resection is best performed for peripheral lacerations with significant bleeding or air leaks. The borders of the injury can simply be "wedged out" using overlapping firings of the linear stapler. For deeper injuries with problematic bleeding, especially "through and through" injuries from projectiles, tractotomy allows the injury to be unroofed, exposing disrupted vessels and airways which can then be controlled directly with clips or suture ligation. Compared to anatomic resections, these techniques spare pulmonary parenchyma and are associated with significantly better outcomes in amenable injuries. At the completion of both tractotomy and nonanatomic resection, the lung should be inspected for evidence of ischemia distal to

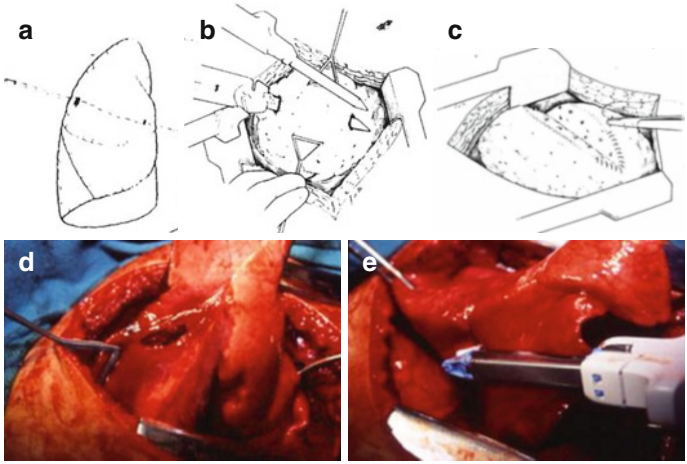

Fig. 6.3 Technique of pulmonary tractotomy. (**a**) Penetrating lung injury amenable to tractotomy. (**b**) Performing the tractotomy with a linear stapler. (**c**) Ligation of parenchymal bleeding and air leaks after tractotomy. (**e**, **f**) Intraoperative photographs illustrating parts **a** and **b** above

the staple lines. Very occasionally a staple line may devascularize a segment of distal parenchyma. When this occurs, a stapled resection of the ischemic area should be performed.

There is little to no role for direct pulmonary repair in lung trauma. Minor peripheral lacerations amenable to this technique either require no repair or are better dealt with by stapled nonanatomic resection. Closure of deeper parenchymal injuries can result in intrapulmonary hematomas or, in a worst-case scenario, can seal together disrupted airways and pulmonary venous branches into the same cavity resulting in air embolism, which can be catastrophic.

Some peripheral injuries that result in massive tissue destruction, such as shotgun injuries, may not be amenable to these parenchyma sparing techniques. In such situations anatomic

resection – generally lobectomy – is necessary. As with pneumonectomy (discussed below), a simultaneous stapling technique using a TA-60 3.5 mm stapler can be used on the lobar vessels and airways, with the 100 mm linear cutting stapler used to complete the fissures.

Proximal parenchymal or hilar bleeding carries a high mortality. Rapid control of the hilum can be obtained by dividing the inferior pulmonary ligament and placing a large vascular clamp across the entire pulmonary hilum. If clamping is difficult, a pulmonary hilar twist in which the entire lung is rotated 180° after division of the inferior pulmonary ligament is another method to gain vascular control (Fig. 6.4). Once these maneuvers temporarily arrest hemorrhage, a more careful attempt to identify the source should be attempted. The use of topical hemostatics and chest packing have occasionally temporarily controlled proximal parenchymal hemorrhage in austere settings and may be viable options for surgeons who do not feel equipped to definitively address these injuries. Such damage control techniques may effectively temporize until the patient can be transferred or a more experienced colleague can arrive; if successful in temporarily controlling hemorrhage, they are probably preferable to repeated unsuccessful attempts at definitive control resulting in ongoing hemorrhage. Very rarely in low-velocity injuries such as stab wounds, a discrete, small, hilar vascular injury such as to the pulmonary vein may be identified that can be primarily repaired after obtaining proximal and distal control. If the injury is distal to the origin of the lobar vessels, the involved lobe should be resected with proximal stapling of the vessels. If bleeding from the proximal hilum still cannot be controlled, or in settings of massive multi-lobar hemorrhage in an unstable patient, a pneumonectomy is the only option. Although trauma pneumonectomy carries a high mortality due to the severity of the injuries that necessitate it and

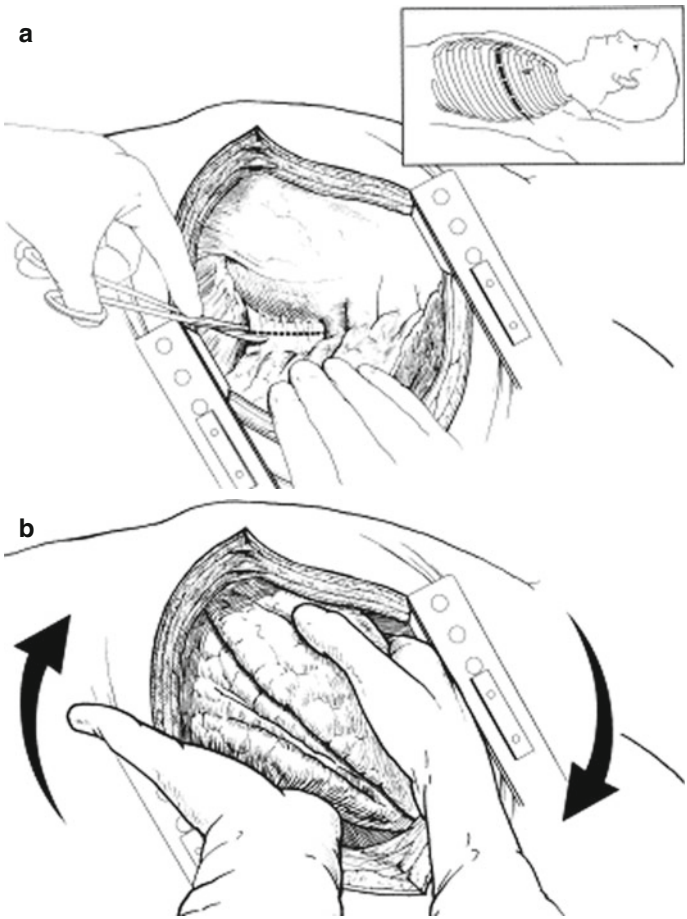

Fig. 6.4 Pulmonary hilar twist. (**a**) Division of the inferior pulmonary ligament is necessary to allow hilar cross-clamping or twisting. (**b**) Rotate the lower lobe anteriorly and the upper lobe posteriorly until the lung is twisted 180°. Packs can be used to maintain this position

the physiologic consequences of pneumonectomy itself, the best hope for a successful outcome in these patients is to recognize the necessity of pneumonectomy early and perform the procedure expeditiously rather than making futile attempts at lung salvage and only moving on to pneumonectomy when the patient is moribund. The optimal technique for trauma pneumonectomy is simultaneous stapled ligation of the hilar structures. This should be performed by passing a 60 or 90 mm long TA stapler with 3.5 mm staples around the hilar structures. One firing is typically adequate, but some authors recommend two firings – one proximal and one 2–3 mm distal – if an adequate length of the hilum is exposed. In either case the hilar structures should be sharply transected beyond the distal staple line and the lung removed.

6.5 Techniques for Airway Injury

Repair of major airway injury is probably the most technically complex procedure in lung trauma. It is important to maintain a high index of suspicion for these injuries and to identify them early as definitive early repair gives the best results. Luckily, these injuries are rarely as urgent as injuries resulting in major hemorrhage and may afford time for involvement of surgeons experienced in airway surgery. As discussed above, flexible bronchoscopy is the critical first step to defining the anatomy of the injury. Small injuries (less than 1/3 the circumference of the airway), especially mucosal ones with minimal tissue loss and no persistent air leak, may be managed nonoperatively with antibiotics, pulmonary toilet, and repeat bronchoscopy to assess for healing. Injuries not meeting these criteria require operative repair.

The distal trachea, carina, right main stem bronchus, and right-sided airways are best exposed through a right posterolateral thoracotomy. The left main stem bronchus (other than

immediately at the carina) and left-sided airways are best exposed through a left posterolateral thoracotomy. The proximal left main stem bronchus is difficult to expose from the left because of the surrounding aortic arch. Simple airway lacerations should be primarily repaired with interrupted absorbable 4-0 sutures (vicryl or PDS) wherever they occur in the tracheobronchial tree. When there is significant associated tissue damage, the devitalized tissue should be debrided, and an end-to-end anastomosis constructed using interrupted sutures as for primary repair. Techniques for carinal reconstruction or long-segment tracheal resection are too complex to discuss here. All repairs and anastomoses should be tested for leaks under water with a continuous airway pressure of 20 cm water and should be airtight. In stable patients we recommend buttressing all airway repairs with tissue flaps – pleura, intercostal muscle, or pericardial fat.

Most parenchymal injuries will be associated with some degree of air leak. It is rare to require surgery to address air leaks associated with peripheral parenchymal injuries, as tube thoracostomy will usually effectively reexpand the lung and allow the air leak to heal with time. Nonetheless, if air leaks are identified at the time of exploration for hemorrhage or other intrathoracic injuries, we do recommend repair. As for injuries resulting in hemorrhage discussed above, peripheral parenchymal injuries should be addressed by either stapled nonanatomic resection or tractotomy with individual ligation of the disrupted airways identified in the wound tract. After tractotomy, if lung isolation has been achieved either by means of a double-lumen endotracheal tube or by advancing a single-lumen tube into the contralateral main stem bronchus, the removal of lung isolation with ventilation of the injured lung can be helpful in identifying small injured airways. Bubbling from the parenchyma is difficult to completely ameliorate, but as long as all identifiable airways have been ligated, these minor parenchymal air leaks will heal with time.

6.6 Postoperative Care

Patients should be extubated whenever possible, though many will require a period of mechanical ventilation. If a double-lumen endotracheal tube was placed for surgery, this should be converted to a single-lumen tube at the conclusion of the procedure. We recommend leaving at least two thoracostomy tubes in place – one anterior and apical, and one posterior and basilar – at the conclusion of any thoracotomy for trauma. We keep tubes to 20 cm water suction until drainage is <200 mL/day and all air leaks have stopped. Pneumonectomy is an exception, in which we recommend leaving a chest tube to water seal drainage for 1–2 days until it is clear there is no significant intrathoracic hemorrhage before removing the tube and allowing the pneumonectomy space to fill. Regional anesthesia considerably improves outcomes in post-thoracotomy patients. We recommend placement of a paravertebral catheter by the surgeon at the conclusion of the procedure while the chest is open or postoperative placement of a thoracic epidural catheter.

6.7 Complications and Their Management

Postoperative bleeding may be due to failure to control a major vascular structure or to the coagulopathy often associated with massive transfusion in trauma. Grossly hemodynamically unstable patients should be returned to the operating room immediately for reexploration. Otherwise, patients will benefit from optimization of their temperature, acid-base balance, and coagulation parameters. This may be enough to arrest bleeding, or at least will allow reexploration to occur under ideal circumstances. Although used less frequently in the chest than in the abdomen, packing and temporary closure may occasionally be

required for control of diffuse coagulopathic bleeding, with later reexploration planned for pack removal.

Retained hemothorax is common in patients with hemothorax managed with chest tube alone or with surgery. If retained hemothorax is suspected on chest X-ray, a chest CT should be obtained to confirm the diagnosis. Additional chest tubes may be required to drain any loculated collection. If this is not successful, then we routinely utilize a 3-day trial of intrapleural tissue plasminogen activator (tPA) in patients who have not undergone thoracotomy. We use this approach more selectively in patients who have recently undergone surgery. We mix 6 mg of tPA in 50 mL normal saline and instill it through the chest tube every 12 h for six doses. The chest tube is clamped for 30 min after each instillation then allowed to drain. If this does not resolve the retained hemothorax, we recommend repeat thoracotomy in post-thoracotomy patients or video-assisted thoracoscopic surgery (VATS) for evacuation of the hemothorax in patients who did not previously undergo surgery.

Empyema is infection in the pleural space. It is treated by complete drainage of the pleural space and appropriate antibiotic therapy. If complete drainage can be achieved with chest tubes alone or with adjunctive tPA, this is adequate. If not, surgery is required. As for retained hemothorax, VATS is preferable in patients who have not recently undergone thoracotomy, but repeat thoracotomy is likely to be needed in postoperative patients.

Persistent air leak should be managed expectantly, as these will almost all heal without direct intervention as long as there is not a bronchopleural fistula from a major airway. Placement of a Heimlich valve allows outpatient management.

Bronchopleural fistula is due to breakdown of the lobar or main stem bronchial closure after anatomic resection. It is suggested by the presence of large or prolonged air leaks, inspiratory air leaks, or progressive subcutaneous emphysema. It is most common after pneumonectomy in which case it presents

with a lowering of the fluid level in the pneumonectomy space, cough that is often productive of copious fluid, and signs of infection. Initial treatment is positioning of the patient with the surgical side down to prevent fluid from spilling into the remaining lung, drainage of the pneumonectomy space by tube thoracostomy, antibiotic administration, and surgical reexploration for washout and flap closure of the dehisced bronchial closure. This is a highly morbid event, and long-term management is complex.

Bronchial stenosis occurs when major airway injuries are unrecognized during the initial presentation, or as a late complication of airway repair. This is treated either with re-resection and anastomosis or with airway dilation and stenting.

Suggested Reading

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