Persistent Pneumothorax

Jose J. Diaz, MD and Hasan B. Alam, MD

Editorial Review: Clay Cothren Burlew, MD
Marc deMoya, MD
Therese Duane, MD
Eric Toschlog, MD
Kimberly A. Davis, MD
Grace S. Rozycki, MD

Objectives: At the completion of this module fellows will be able to:

1. **Define persistent pneumothorax after trauma.**
2. **Discuss a logical management strategy.**
3. **Identify the key operative steps and post operative issues.**

Background

- A traumatic pneumothorax (PTX) is the most common thoracic injury following blunt or penetrating trauma. About 80% of all traumatic injuries to the chest can be managed with a tube thoracostomy (TT), without need for more invasive interventions. Once the lung has expanded and the pneumothorax has resolved the TT can be removed.
- Persistent pneumothorax (PP) is a common occurrence, evident in 10-30% of patients.
- In a study of 710 patients with a TT during their index admission, 21% had a documented PP on chest radiography after tube removal. Of these 151 patients with PP, 35 had outpatient imaging which demonstrated a PP in 16 patients (45.7%). The presence of a PP at discharge was associated with a higher re-admission rate (6.6% vs 0.7%) but the overall complication rate remained low.

Evaluation/Diagnostics

- Persistent pneumothorax (PP) is defined as a pneumothorax that is present for more than 10 days. This may also manifest as a continuous air leak.
- Although, a PP is commonly the result of injury to the lung, one must rule out the possibility of a bronchial injury. This is especially true if the air leak is large and other mechanical reasons associated with the TT (e.g. leaky connections, partially pulled out tube) have been excluded. In this sub-group of patients, bronchoscopy should be considered to identify an injury that may require an intervention (surgical repair, bronchoscopic glue application, etc).
- A computed tomography (CT) scan of the chest may be helpful in cases of PP to identify the extent of the injury, rule out underlying pre-existing lung disease (e.g. COPD), and identify complicating features (e.g. broken ribs embedded in the lung parenchyma).

Management

- Non-operative Management:
  - A TT should be left in place. Randomized trials have demonstrated equivalence between a smaller bore (14Fr pigtail) versus a larger 28-36Fr TT for treatment of a pneumothorax. If the lung is inflated and an air leak is minimal, the lung will seal in a 7-10 day period.
  - More commonly in trauma, a lung laceration or a ruptured bleb may be the cause of a PP. The goal of treatment is to completely expand the lung in order to approximate the visceral pleura against the parietal pleura. If a PP remains despite suction, several options exist:
    - Insert a second TT or an IR placed catheter in an attempt to evacuate the PP and fully expand the lung. This will commonly result in healing of the lung injury. On

occasion the initial TT may be in the pulmonary fissure and not functioning properly.
    - Increasing the suction on the TT from -20 to -40 cm H_20 will anecdotally work sometimes, but it typically fails to fix the problem. If the tube is in a good location and is of appropriate caliber, increasing the negative pressure does not significantly change the flow rate through the tube. Most often the tube is not working well and a new or additional tube is a better option.
    - In mechanically ventilated patient, positive pressures should be minimized to decrease the air leak from the site of the lung injury. Whenever possible, plateau pressures (pressure exerted in the small airways and alveoli) should be kept <30 cm H_2O. Although positive end expiratory is less relevant as most of the air leak takes place during insufflation, it is prudent to avoid excessively high PEEP (>10 cm H_2O) if possible. Patients should be extubated as soon as possible.
    - Chemical pleurodesis, used commonly for malignant effusions and PP due to emphysema, is not typically indicated in the setting of a traumatic PP. A limited indication would be the trauma patient with pre-existing emphysema who is not a good surgical candidate.
    - If a pneumothorax persists beyond 2 weeks despite adequate TT placement, one must decide whether surgery is indicated.
- Indications for Surgery:
    - In the face of a PP beyond a week, or a recurrent large PTX after removal of the TT, a CT scan should be obtained to delineate the extent of the lung injury and to rule out the presence of underlying conditions or complications, such as pre-existing lung disease or a traumatic bleb/laceration.
    - If an air leak persists beyond two weeks one should consider operative intervention.
    - If the PP is likely to be the result of a ruptured apical bleb, earlier operative intervention may be considered.
- Preoperative Preparation:
    - CT scan of the chest: Prior to any operative intervention a CT scan of the chest is helpful for operative planning and possible localization of the injury.
    - Standard preoperative preparation should include:
        - Tolerance of single lung ventilation- patients on ventilatory support will need careful assessment. Patients with an associated pulmonary contusion may not tolerate single lung ventilation. Bedside evaluation with a bronchial blocker or even re-intubation with a double-lumen endotracheal tube may aid in this determination.
        - Cardiopulmonary optimization should be accomplished pre-operatively.
        - Poly-trauma patients often have other injuries that have to be taken into account. For example, extremity or spine injuries can make surgical positioning challenging, and requires discussions with the spine and orthopedic surgeons. Similarly, patient with external fixation devices may need adjustment of the devices for appropriate positioning on the operating table. Patients with traumatic brain injury may not tolerate a thoracic procedure due to an increase in intracranial pressures.

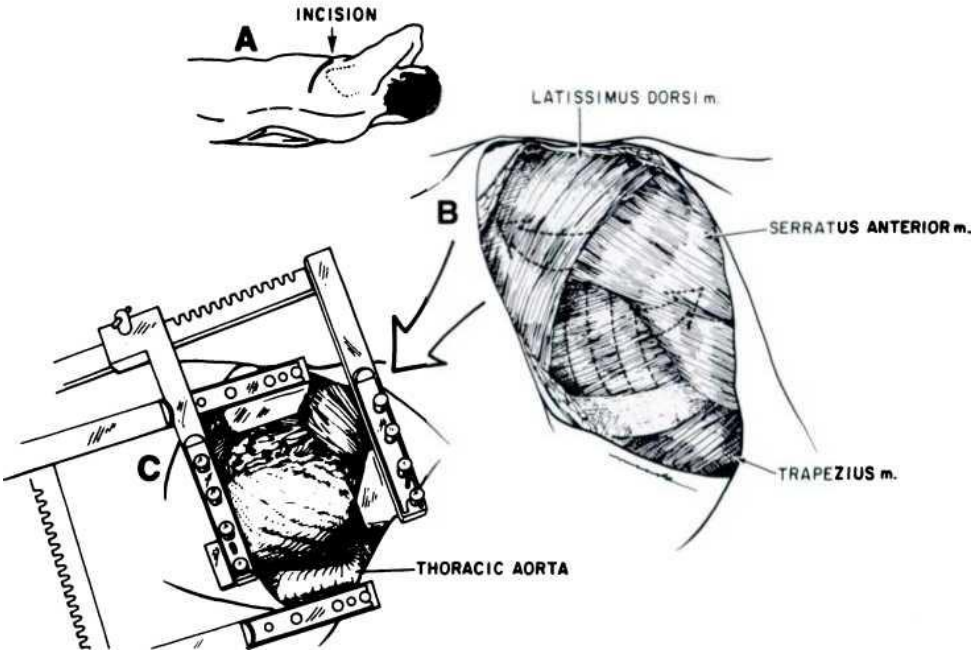
Operative Technique

- Minimally Invasive Procedure: Video-assisted Thoracoscopic Surgery (VATS) is the preferred approach:
  - Positioning: Lateral decubitus position.
    - Axillary roll is necessary for positioning of the shoulder
    - The upper extremity is best positioned in a dedicated upper extremity arm rest
  - Timing: For patients who have isolated PP that has not resolved with non-operative maneuvers or continue to have persistent PP beyond 2 weeks.
  - Advantages: VATS is better tolerated and has lower postoperative pain and complications compared to thoracotomy.
  - Patients should have a double lumen tube placed for maximal deflation of the lung. Occasionally, a bronchial blocker can be used. An arterial line for continuous blood pressure monitoring, and adequate IV access to provide resuscitation is essential.
  - The essential equipment includes 3 thoracoscopic 10 mm ports (sometimes smaller 5 mm ports can be used), thoracoscopic instruments, 10 mm suction cannulas for evacuation of retained hemothorax, 30 degree 10 mm videoscope. Suggested port positioning is 1) anterior axillary line at the 4-5th intercostal space, 2) mid-axillary line at the 6-7th intercostal space, 3) posterior axillary line at the 7-8th intercostal space. The procedure is typically started with the camera in the middle port, but it may have to be moved depending upon the area of the injury. All ports should be separated by 6-8 cm in order to avoid unnecessary fencing of intrathoracic instruments.
- If a parenchymal injury is found, the most common approach is to perform a stapled non-anatomic wedge resection. In patients with apical blebs or with significant emphysematous disease, the use of either gortex or biologic strips over the mechanical stapler has been shown to decrease the incidence of post-operative staple line air leaks.
- Thoracoscopic suture repair of an injury can be performed. Another option is the use of topical sealants to cover the laceration.
- Open Procedure: Thoracotomy is another option for PP, but is being rapidly replaced by VATS at most centers.
  - Positioning: Lateral decubitus position
    - Axillary roll is necessary for positioning of the shoulder
    - The upper extremity is best positioned in a dedicated upper extremity arm rest
  - Indications to convert to or consider open thoracotomy as the first line option:
    - Failed VATS: 1) the lung cannot be decompressed, 2) adhesions preclude safe access, 3) safe thoracoscopic manipulation of the lung is not possible.
    - Concomitant injuries that require an open approach.
    - Patient does not tolerate single lung ventilation.

Intraoperative Considerations

- The posterolateral approach allows for maximal exposure into the chest cavity; dividing the latissimus dorsi muscle is individualized based upon operative exposure requirements. This approach appears to have the most post-operative pain.

- The anterolateral approach is more limited and can be performed with the patient in a supine position with access to the anterior abdomen. This is most appropriate for an emergent thoracotomy, so as to have access to the abdomen.
- Muscle sparing thoracotomy can be performed with either an oblique incision or a combination of a partial posterior and anterior lateral thoracotomy. The latissimus dorsi is retracted but not divided, and the anterior serratus muscle is divided.
- Endoscopic staplers are used for wedge resection of the injury.
  - Standard GIA staplers can be used for lung resection using bowel height staples.
  - Endostaplers must be used during a VATS; due to their longer handle length, these may also be easier to use in open surgery. Commercially available brands have articulating and flexible arms.
- A Bovie pad or "a sponge on a stick" may be used to gently abrade the parietal pleura to perform a mechanical pleurodesis.
- Two TT should be left in place: one straight TT is placed anteriorly and a second tube is either a straight tube placed posteriorly or curved/right-angle chest tube placed in the costophrenic recess.



Postoperative Management and Potential Complications

- Postoperative chest radiograph should be obtained to confirm adequate lung expansion.
- Maintain TT to suction (-20cm H_2O) until the air leak has resolved and/or pneumothorax has resolved as they may have different etiologies and treatments.
- Actively reverse coagulopathy.
- Use a restrictive fluid resuscitation strategy.
- Keep the head of bed elevated $\geq 30°$ if not contraindicated.
- Ensure that the TT is patent and draining properly.

- Ensure adequate respiratory support; positive pressure ventilation (invasive or non-invasive) may be necessary in the first 24 hours to recruit the collapsed pulmonary segments.
- Check serial hemoglobin level and chest tube output to monitor for ongoing bleeding.
- If the chest radiograph appearance worsens after first 48 hours, perform chest CT scan to rule out accumulation of blood versus lung consolidation or pleural reaction.
- Antibiotics should not be used routinely, aside from a single pre-operative dose.
- Physical therapy and incentive spirometry are important adjuncts to mobilize the patient and clear the airway of secretions.
- Adequate pain control should be provided. In addition to local injections, infusion therapies such as epidural analgesia, pain catheters, or patient controlled administration of IV narcotics should be used to ensure adequate deep breathing.
- TT should be removed post-operatively as quickly as possible to decrease the risk of empyema.

Long-term Outcomes

- Determined by the number of rib fractures, presence of a flail segment, extent of the pulmonary contusion, presence or absence of pre-existing lung disease and major bronchial injury, as well as the type of operation, rather than the PP itself.
- Most patients continue to show significant improvement over time, returning to baseline pulmonary function.
- Competitive athletes may notice reduced pulmonary function that prevents similar levels of competition.

Special Populations

1. Pediatric
    - Compliance of thoracic cage allows for significant bending of the ribs and sternum resulting in transmission of high energy force to the internal structures without fracture of the ribs.
    - Data regarding optimal management strategies are limited in pediatric populations, but the basic principles are similar to adults.

2. Geriatric
    - No specific data are available for this patient population related to outcomes after PP.
    - Special consideration for those on anti-coagulation therapy -- more aggressive radiographic follow up may be warranted to rule out bleeding.
    - Much more likely to have underlying lung disease as an etiology for the PP.

3. Immunocompromised
    - No specific data are available for this patient population related to PP outcomes.
    - As retained blood is a nidus for infection, aggressive evacuation should be pursued to minimize risk of empyema.

Pearls from the Experts – Drs. Rao Ivatury and James O'Connor

- Pneumothorax (PTX), spontaneous or after trauma mostly requires a well-placed chest tube. Persistent pneumothorax (PP) usually is a problem of continuing air leak that is not adequately drained. I give a lot of attention to keeping the chest tube patent and draining well by appropriate placement, suction and maintenance of patency. Prevention, therefore plays a large part.
- Small chest tubes (and pigtail catheters) are just as effective as large chest tubes for uncomplicated PTX. Larger chest tubes are very painful for the patient and prevent good, deep breathing. Only for a large hemothorax do I reach for a large tube (never bigger than a 32 F).
- PP results, usually, from large lung lacerations with air leak. The air collects in a space that is walled off from the chest drain by irregular expansion of the lung. Of course, if the lung leak gets sealed off and the pneumothorax is not expanding in a patient that has good respiratory parameters, it may be left alone to resolve spontaneously. If small and persistent, it can be aspirated with a small catheter. If persistent, adding more chest tubes is morbid without addressing the problem. It is important to localize the pneumothorax in 3 dimensions and place a chest tube precisely in the cavity. This is usually best accomplished by ultrasound or CT-scan guided chest drain.
- In the setting of PP or ongoing air leak, one must rule out more serious causes such as an underlying bronchial injury, major pulmonary laceration, pre-existing lung disease with pulmonary blebs. CT scan of the chest and/or bronchoscopy is indicated to establish the underlying causative factor.
- Bronchial injuries and major pulmonary lacerations need appropriate surgical treatment: repair with absorbable sutures for bronchial injury and tractotomy or wedge resection with endo-stapling device for pulmonary lacerations.
- If PP or air leak persists beyond 7-9 days, spontaneous resolution is unlikely. I plan for surgical intervention with VATS and pleurodesis with mechanical abrasion, if the patient has no chronic lung disease.
- If PP or air leak occurs in a patient with advanced chronic lung disease, non-surgical options must be considered. When air leaks are from multiple sites following pulmonary resection or if air leaks persist in patients with a spontaneous pneumothorax, using autologous blood for pleurodesis may be safe and effective. The dose of blood required for autologous blood patch pleurodesis usually is about 1 mL/kg blood.
- Endo-bronchial valves (EBV), placed over a bronchoscope, is a newer, non-surgical, minimally invasive therapeutic option that may be appropriate for the treatment of persistent air leak, especially in high-risk patients. EBVs obstruct the bronchial airway, causing parenchymal atelectasis. The formed atelectasis possibly results in the cessation of the air leak. Most of the experience with EBV is reported with persistent air leak after major lung resection.
- In summary, PP should be an infrequent complication that can be prevented by an appropriately placed and cared for chest tube. If happens, it usually resolves. Avoid the temptation to place multiple chest tubes. If persistent beyond 48-72 hours, drain by radiology-directed catheters or tubes of a small size. Exclude the rare bronchial injury.

Consider VATS by the end of the first week for persistent air leak and/or PP and non-surgical approaches for PP with advanced COPD.

- PTX, whether spontaneous or post-traumatic, generally can be managed by a chest tube. Appropriate chest tube placement is more important than chest tube size. A larger chest tube (≥32 Fr.) may be necessary if there is a concomitant hemothorax. The presence of tidaling with respirations confirms intra-pleural chest tube placement, and CXR will confirm full lung expansion. It is important to keep the system patent and initially on suction.
- The management of a persistent PTX (PP) depends on the clinical setting. It is also important to identify the reason the PTX did not resolve with the first chest tube. An asymptomatic, small, residual PTX may be observed or managed with a pleural catheter (pigtail). A larger or symptomatic PTX requires drainage, either a second chest tube or a pigtail. A chest CT is useful prior to placing a second chest drain, defines the precise location of the PTX. In addition, the chest tube/ pigtail can be placed by the interventional radiologist using ultrasound or CT to guide placement. If the PPT resolves and there is no air leak the chest drains are managed in the usual fashion.
- A PP with a persistent air leak is managed differently. While there is no universally accepted definition of "persistent" most would agree an air leak lasting more than 7 days meets the definition and is not likely to spontaneously resolve. Lung lacerations, underlying COPD/bullous disease and a high airway pressure in the ventilated patient can all contribute to a persistent air leak. Examining the drainage system daily to qualitatively assess the size of air leak, and radiographic evidence of a PP are important. Air leak which is decreasing over time and a CXR which shows a fully expanded lung may warrant a few more days to resolve. If there is no change in the air leak and/or the CXR demonstrates PP then additional diagnostic studies are warranted. A chest CT and bronchoscopy are essential. CT may diagnose a parenchymal laceration or bullous disease. Bronchoscopy will evaluate for a possible tracheobronchial injury. Management will be individually addressed.
- A tracheobronchial injury or parenchymal lacerations require operative intervention. Airway injuries are best managed by thoracotomy and direct repair. Lung lacerations are treated using stapling devices and are approached by muscle sparing thoracotomy or, preferably VATS. Placement of a double lumen endotracheal tube facilitates the operative procedure.
- Clearly decreasing the airway pressure and extubation are strategies for the intubated patient. If this cannot be accomplished then CT and bronchoscopy are performed and the management is as outlined above.
- The most common clinical scenario is PP, a persistent air leak or both. In a patient without bullous disease waiting 7 to 10 days for an air leak, which shows no signs of abating, may prolong the hospital course. Generally between 5 and 7 days a decision can be made that a procedure is necessary. While treatment options, including autologous blood patch, chemical pleurodesis (for PP without air leak) and VATS, the latter is the preferred approach. VATS with mechanical pleurodesis is well tolerated, has a low recurrence rate and patients recover rapidly. It does require single lung ventilation and if not tolerated then I prefer a limited muscle sparing thoracotomy. Whichever approach is chosen adequate post-operative analgesia (epidural, paravertebral, PCA) and pulmonary toilet are essential. I reserve talc pleurodesis for the treatment of malignant effusion. The

inflammatory response is profound, the pleura become quite thickened thus complicating subsequent thoracic operations.

- A non-operative approach for a persistent air leak in the patient with COPD and bullous disease is the preferred strategy. Often these patients are on mechanical or non-invasive ventilation but even if they are not ventilated, operative intervention is associated with significant morbidity. Treatment options include an autologous blood patch, converting to a Heimlich valve or operation with its attendant complications. Recently endobronchial valves have been shown to be very effective.

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