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Tube Thoracostomy

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INTRODUCTION

Intercostal chest tube placement (tube thoracostomy) is a procedure that is commonly performed in the emergency department, intensive care setting, and even the general wards. The aim of chest tube placement is drainage of abnormal collection of air or fluid from the pleural space. First described by Hippocrates in the fifth century, there have been several modifications of the intercostal tubes and the drainage systems used. Although a very simple procedure, an improperly placed tube can lead to life-threatening complications.[1,2] In this chapter, we review in detail the technique for placement of an intercostal tube.

INDICATION

- *Pneumothorax:* A pneumothorax is defined as the presence of air in the pleural cavity. Pneumothoraces can be classified as traumatic, spontaneous (primary or secondary) or iatrogenic. All pneumothoraces do not need placement of a chest drain.
  - *Primary spontaneous pneumothorax:* The British Thoracic Society (BTS) guidelines[3] recommend single time manual aspiration of pneumothorax if the size is greater than 2 cm or the patient is breathless, and recommend insertion of a small bore chest drain only if manual aspiration fails (pneumothorax >2 cm or persistent symptoms despite aspiration). The American College of Chest Physicians (ACCP) Delphi statement also recommends insertion of chest drain only if the pneumothorax is large (apex to cupola distance ≥3 cm) or if the patient is clinically unstable (defined as any one of the following: respiratory rate >24/min, heart rate >120/min, room air oxygen saturation <90% or unable to speak whole sentences in a single breath).
  - *Secondary spontaneous pneumothorax:* Most authorities recommend performance of tube thoracostomy in all symptomatic patients with secondary spontaneous pneumothorax.[3-5] Even patients with smaller pneumothoraces need to be closely monitored for progression of size or symptoms. Manual aspiration is usually not recommended for secondary spontaneous pneumothoraces as it is unlikely to be successful. Moreover, all patients require chemical pleurodesis, which can only be performed with chest tube in the pleural cavity.

- *Iatrogenic pneumothorax:* The incidence of iatrogenic pneumothoraces is increasing due to the explosion of invasive diagnostic and therapeutic modalities. As recurrence is not an issue in the management of iatrogenic pneumothorax, the management mainly focuses on relieving the patient's symptoms with the least invasive approach possible. The common causes of an iatrogenic pneumothorax include transthoracic needle aspiration, transbronchial lung biopsy, placement of subclavian catheters and diagnostic thoracentesis. The factors deciding the treatment strategy include the presence or absence of underlying lung disease, clinical status of the patient and size of the pneumothorax. Most cases can be successfully management by close observation, oxygen supplementation and single time aspiration. A chest drain is indicated only if the underlying lung is diseased, the patient is clinically unstable or deteriorating, or if the conservative approach fails.
- *Traumatic pneumothorax:* Pneumothorax is the second most common complication of chest trauma after rib fracture and is seen to occur in up to 50% of chest trauma patients. All overt traumatic pneumothoraces are managed with a chest drain insertion. An occult pneumothorax (defined as that not obvious on initial chest radiograph but is detected on subsequent imaging like a computed tomography scan or a subsequent chest radiograph) is also common. Although some recommend placing a chest drain even in occult pneumothoraces, a more conservative approach may also be considered. However, if mechanical ventilation is anticipated, even an occult pneumothorax may be treated with a chest drain.

It is also important to remember that most pneumothoraces in a mechanically ventilated patient or any pneumothorax that causes hemodynamic instability (tension pneumothorax), should be drained with a chest tube.

- *Pleural effusion:* A chest drain in pleural effusion is placed with the aim of relieving patient's symptoms or drainage of pleural contents (pus, blood). The indications of chest drain include rapidly reaccumulating pleural effusion (usually in cases of malignancy and occasionally in those with benign diseases like uremia), empyema or a complicated parapneumonic effusion (pleural fluid glucose <60 mg/dL, pH <7.2, Gram stain or culture positivity) and hemothorax (spontaneous or traumatic).
- *Post-surgery:* Chest drains are also routinely placed following thoracic or cardiothoracic surgeries.

CONTRAINDICATION

There is no absolute contraindication for the placement of a chest drain. The relative contraindications include:

- *Bleeding diathesis:* Deranged clotting profile or thrombocytopenia needs to be corrected before the procedure provided the indication is not an emergency.
- *Trapped lung:* A trapped lung is identified by the presence of a thick fibrous pleural peel resulting from a remote pleural space infection, which prevents the lung from expanding on fluid removal. A chest tube should not be placed as the lung does not expand.

- *Endobronchial obstruction:* A complete endobronchial obstruction on the side of pleural effusion (which might coexist in malignant pleural effusions) is also a contraindication for chest tube placement as the lung will not expand even if the fluid is drained. It can be suspected by lack of contralateral mediastinal shift on chest radiograph, and lack of improvement in dyspnea following a therapeutic thoracentesis.
- *Loculated effusion:* This is a contraindication for blind placement of a chest drain. An image-guided chest drain or a pigtail should be placed.

APPLIED ANATOMY

It is essential to know the anatomy of lungs and pleura for comfortable performance of the procedure and prevention of complications. The usual site for the placement of chest drain is the triangle of safety, which is bounded anteriorly by the lateral border of pectoralis major, posteriorly by the anterior border of latissimus dorsi and inferiorly by an imaginary line drawn at the level of the nipple. The apex of the triangle is formed by the axilla. This usually corresponds to the fourth or fifth intercostal space in the midaxillary line. The safe triangle avoids damage to the internal mammary artery and also avoids dissection through the muscles and breast tissue (Fig. 1). The midaxillary line is chosen because the innermost layer of intercostal muscle is poorly developed at this point and also it is more comfortable to the patient and allows him/her to lie down supine. A more posterior approach though feasible makes lying down supine uncomfortable for the patient. Also there is chance of injury to the long thoracic nerve which lies on the surface of serratus anterior and segmentally supplies this muscle.

There are three layers of intercostal muscles (the external intercostal, internal intercostal and innermost intercostal) between the ribs (Fig. 2). As the intercostal neurovascular bundle lies in the groove on the inferior margin of the superior rib, the chest drain is typically inserted just superior to the lower rib so as to avoid injury to the same. However, as the collateral intercostal vessels run along the superior margin of the inferior rib, the ideal site for insertion should be 50–70% of

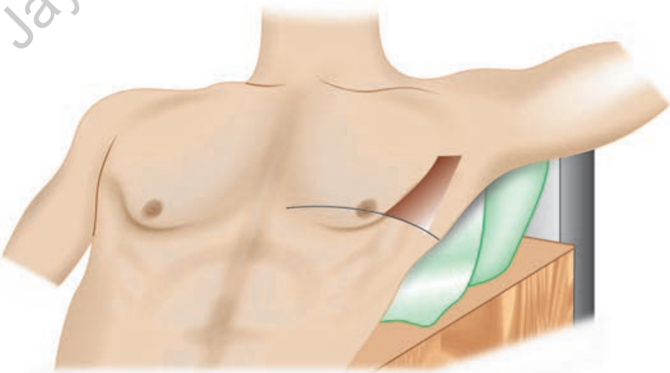

Fig. 1 Diagram to illustrate "safe triangle"

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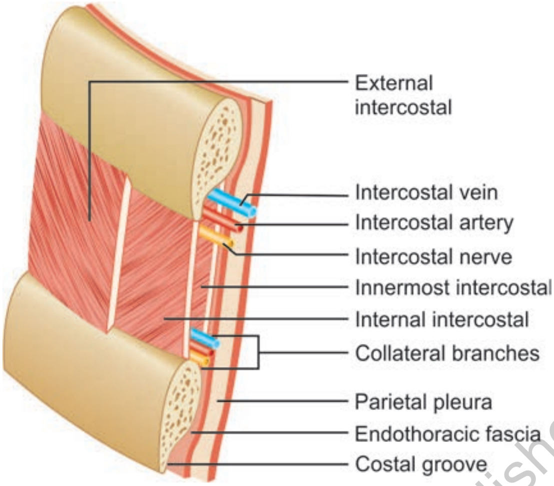


Fig. 2 Anatomy of the intercostal space

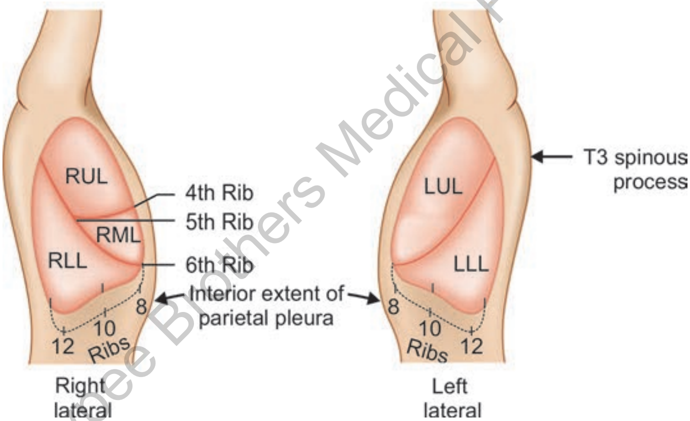


Fig. 3 Surface marking of pleura and lung fissures (Lateral view of the chest)

the way down the intercostal space.[6] Despite adequate precautions, injury to the neurovascular bundles remains a potential complication of the procedure.

The inferior margin of the parietal pleura lies at the eighth, tenth and twelfth ribs in the midclavicular line, midaxillary line and lateral border of the erector spinae respectively (Fig. 3).[7] However, the superior border of the diaphragm lies at much higher levels, especially in expiration (fourth space on right side and fifth on the left side). Hence, a drain placed too low can traverse the pleural space and injure the diaphragm and also the intra-abdominal organs, if undue force is used. The major fissure runs from the second spinous process posteriorly to the sixth costochondral junction anteriorly and cuts the midaxillary at the fifth rib. The minor fissure runs horizontally from the fourth costochondral junction to cut the oblique fissure at the fifth rib. Hence, there is a high chance of intrafissural placement of the tube if it is placed at the midaxillary line in the safety triangle and not angulated upward.

TECHNIQUE AND EQUIPMENT

There are three methods of insertion of chest tube: blunt dissection into pleura (operative tube thoracostomy), Seldinger guidewire technique (guidewire tube thoracostomy), and trocar tube thoracostomy.[8,9]

1. *Operative tube thoracostomy:* Blunt dissection into the pleura is the oldest and probably the safest technique for chest drain insertion. This is the most commonly used technique in resource-constrained settings and is typically used when larger bore tubes have to be placed. The advantages of this technique include the ability to perform digital exploration of the pleural space and therefore direct the tube into the most appropriate position in the thoracic cavity. However, this is also the most painful technique as it needs a larger incision and also leaves a larger scar.
2. *Guidewire tube thoracostomy (Seldinger technique):* With an increasing trend toward the use of smaller chest tubes and pigtail catheters, this Seldinger technique is more commonly being used now. This technique also causes less pain, is more patient-friendly and does not leave an unsightly scar. Commercial kits are available for guidewire tube thoracostomy. Chest tubes of varying sizes (8–36 Fr) can be inserted with this technique.
3. *Trocar tube thoracostomy:* This is similar to the guidewire technique except that there is no sequential dilation. Considerable force is used while inserting the metal trocar into the pleural space, thereby increasing the risk of damaging internal organs. This technique is not recommended for routine use.

Equipment

The equipment needed for operative tube thoracostomy include: (1) chest tube (of the desired size); (2) underwater seal bag of the desired type (described below); (3) normal saline (to be filled in the water seal bag); (4) chest tube insertion tray (scalpel, blunt-tipped artery forceps, scissors, nonabsorbable suture with a cutting needle, needle holding forceps, syringes, sterile drapes, sterile dressings, cotton and gauze); (5) local anesthetic agent (usually lignocaine); (6) sterile skin preparation solution (povidone iodine, chlorhexidine); (7) sterile gown, face mask and cap (Fig. 4). Commercial kits with sequential dilators are available for guidewire tube thoracostomy.

Fig. 4 Equipment needed for operative tube thoracostomy

Intercostal Drainage Tube

Intercostal tubes/drains are hollow cylindrical tubes made of polyvinyl chloride or silicone designed to be placed within the pleural cavity. They also have side holes designed to increase the surface area of absorption of fluid or air and to allow alternate path for drainage in case the tip of the tube gets blocked. A radiopaque strip is present on the side of the chest tube to assist visualization on chest radiographs. The most proximal hole on the chest tube, the sentinel eye, is usually situated on this strip and is visible on the chest radiograph as a defect in the line. The position of this sentinel eye helps us ensure that all the holes are inside the pleural cavity (Fig. 5). The length markings on the tube note the distance of the sentinel eye from the skin insertion site.

Chest tubes come in varying sizes ranging from 6 French (Fr) to 40 Fr (The Fr refers to the outer diameter of the cylindrical tube and is equivalent to 0.333 mm). The flow rate however is determined by the chest drain's internal but not external diameter. This varies even amongst tubes of the same external diameter due to differences in the wall thickness. Chest tubes are classified as small bore and large bore chest tubes. The ACCP Delphi consensus statement has classified tubes into three categories: small (≤14 Fr), medium (16–24 Fr) and large (24 Fr and above).[7] Others have used cutoffs ranging from 14 to 20 Fr to differentiate small from large bore chest tubes.[8,10]

There is an increasing trend to use small bore chest tubes for pleural drainage. The traditional concerns raised against the use of small bore chest tube are the low flow rates, and the increased tendency to get blocked, kinked or displaced.[11] However, several recent studies have disproved these concerns and have shown that even small bore chest drains can effectively drain fluid and air from the chest. Other advantages of small bore chest drains include less pain, more patient comfort and smaller scars. The only indications for placement of large bore chest drains are pneumothorax in a mechanically ventilated patient (to effectively drain larger

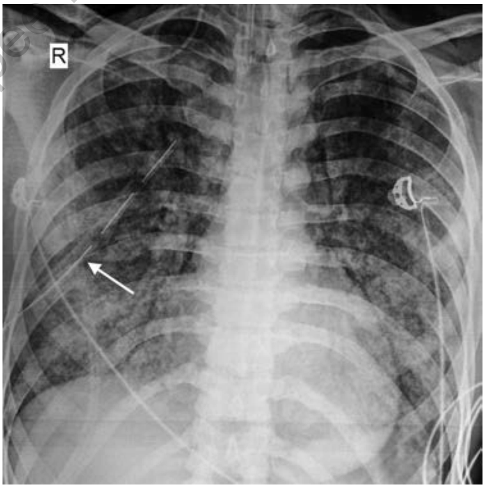


Fig. 5 Chest radiograph showing an intercostal tube placed in the right pleural cavity. Note the radiopaque line (arrow) on the chest tube with side drainage holes visualized as defects in this line. Also note the fully expanded lung

air leaks which are expected), hemothorax and empyema (as there is an increased chance of tube blockage when small bore tubes are used).[8,10] Recent studies have shown that even empyemas can be effectively drained using small bore chest tubes with periodic flushing and use of intrapleural fibrinolytic agents.[12,13]

Intercostal Drainage Bags

There are various types of drainage systems which can be connected to the chest tube. Conventionally, glass or plastic bottles were used for pleural drainage. However, these have been replaced by various types of ambulatory drainage systems. The collection bags are purely gravity-assisted drainage systems or gravity plus negative suction-assisted drainage systems. There are also waterless variants of these drainage systems. The basic principles of underwater seal drainage are best understood with the bottle system,[9,14] which shall be briefly described here. The various types of bottle systems are:

One-bottle system: The same chamber acts both as a water seal and a collection chamber (Fig. 6). The drainage tube extends into a sterile plastic or glass bottle such that it is submerged 2 cm under the level of sterile saline. Air escapes from this chamber to the atmosphere via an exit vent which should always be kept open. As the collection chamber fills with blood or fluid, the drainage tube becomes submerged to a greater depth and this results in an increased resistance to drainage. A regulated suction cannot be applied to this system.

Two-bottle system: There are two bottles, the one proximal to the patient acts as a collection chamber and the other one acts as a water seal chamber and has the air vent (Fig. 7). Blood or fluid drains into the proximal collection chamber and only the air flows into the underwater seal chamber and escapes through the air vent. This ensures that the underwater seal is always kept at a fixed level. Thus, there is no increase in resistance as the fluid gets drained and is ideal when large amount of fluid needs to be drained. A regulated suction cannot be applied to this type of drainage system also.

Fig. 6 One-bottle drainage system

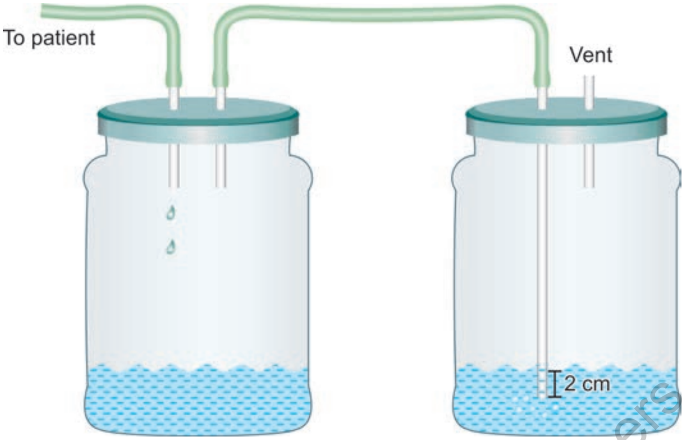


Fig. 7 Two-bottle drainage system

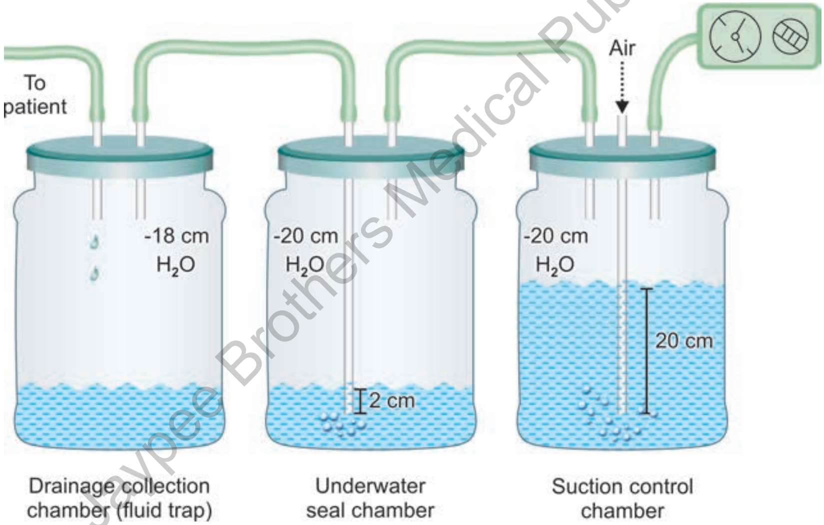


Fig. 8 Three-bottle collection system

Three-bottle system: This is designed for safe application of negative suction pressure and involves the addition of a suction control bottle between the underwater seal and the suction apparatus (Fig. 8). The suction control chamber is connected to the exit vent of the underwater seal on one end and the suction device on the other end. This chamber also has a control tube which is immersed approximately 20 cm in water and is open to the atmosphere. The depth to which the control tube is immersed determines the upper limit of negative pressure in the system. The major disadvantages of the three-bottle system are greater complexity, noise due to continuous bubbling in the third bottle, and lack of an exit vent if suction fails.

Four-bottle system: The four-bottle system consists of a fourth bottle, a safety underwater seal which is connected to the collection chamber (fluid trap) of the three-bottle system (Fig. 9). This will vent the entire system and relieve any pressure build-up in case of a failure of suction.

Ambulatory Drains

These are basically modifications of the traditional bottle systems with which the patient can ambulate.[15] The simplest of these, the Heimlich valve, needs special mention. Heimlich valve is a one-way flutter valve (Figs 10A and B), which is constructed such that the tubing gets occluded whenever the pressure inside the tubing (same as the intrapleural pressure) is less than the atmospheric pressure (inspiration) and is patent when the pressure inside the tube is above atmospheric pressure (expiration). As there is no collection chamber attached to this valve, this is most useful for patients with pneumothorax where there is no fluid which needs to be drained. It is also important to know that if attached in the wrong direction, it can lead to a tension pneumothorax.

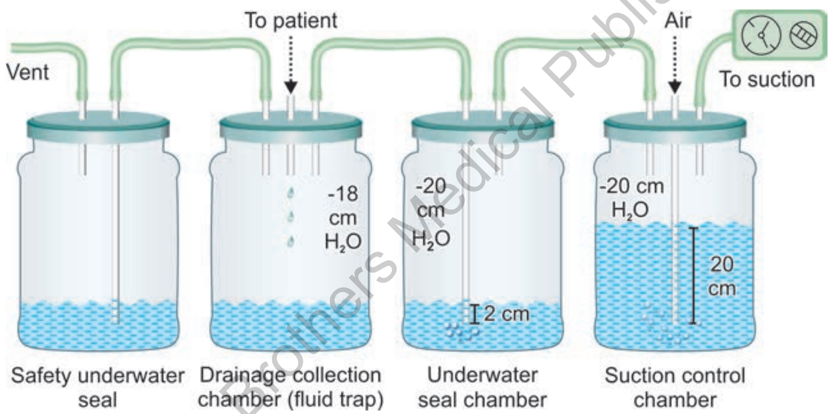
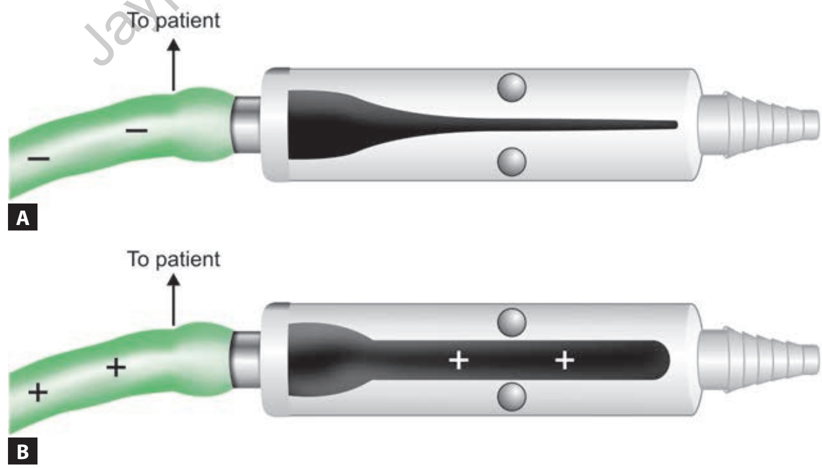


Fig. 9 Four-bottle collection system



Figs 10A and B Heimlich's valve—schematic diagram. (A) During inspiration; (B) During expiration

PREPARATION

Informed Consent

Prior to starting the procedure, the patient (or his/her relatives) should be informed about the indication for chest tube placement, the procedure itself and its attendant complications, and a written informed consent should be obtained.

Patient Preparation

- The indication for chest tube insertion should be reconfirmed and any contraindications if present should be ruled out.
- The side of placement of intercostal drain should be reconfirmed by auscultation and chest radiograph.
- *Positioning the patient:* The preferred position for intercostal drain insertion is patient lying supine with the arm on the side of the lesion behind the patients head so as to expose the axillary region. Chest drains can also be inserted with the patient lying in lateral decubitus position with the affected side facing upward. Some authors have also described placing chest tube with the patient sitting and leaning forward with the arms resting over an adjacent table or a pillow. We do not recommend this position as there is a possibility of vasovagal syncope during the procedure.
- *Establishing an intravenous access:* It is important to have a functional intravenous access before starting the procedure so that no time is wasted in securing an access in the event of an emergency.
- It is advisable to monitor the pulse rate, blood pressure and arterial saturation throughout the procedure. Patients may need supplemental oxygen during the procedure.
- *Premedication:* As intercostal drain placement is a painful procedure, adequate analgesia needs to be given. BTS guidelines recommend the use of an anxiolytic/sedative, either a benzodiazepine or an opioid, before the procedure. However in patients who are prone to respiratory depression, e.g. patients with chronic obstructive pulmonary disease (COPD), deep sedation should be avoided.

PROCEDURE

Operative Tube Thoracostomy[3,16]

Identifying the Site of Insertion

The most common site for chest tube insertion is the safe triangle in the midaxillary line (Fig. 11A). Once identified, it is preferable to mark the site of insertion with a skin marker. We usually perform a chest ultrasonography in the presence of loculations. If there are extensive adhesions, an image-guided pigtail insertion is then performed. It was earlier thought that the chest drain should be placed more superiorly, in the second intercostal space in midclavicular line for draining a pneumothorax. However, it has been shown that lateral placement of chest tube through the midaxillary line drains pneumothoraces equally well.

Skin Sterilization

Chest tube insertion should be performed under strict aseptic precautions. The operator and the assistant should wear a sterile gown, face mask, cap and gloves. The patient's skin should be disinfected from the axilla to the iliac crest and from the nipple line to the midline posteriorly. Thereafter, the area should be draped with sterile towels on all sides, leaving only a few inches exposed on either side of the proposed site of insertion (Fig. 11B). It is necessary to prepare and drape a wide area so that asepsis is not breached during the procedure. Failure of asepsis may lead to iatrogenic wound site infection and may even turn an uncomplicated effusion into an empyema. The role of prophylactic antibiotics to prevent wound infection is controversial. In the setting of chest trauma (penetrating or blunt), a meta-analysis found the use of prophylactic antibiotics beneficial (decline in the absolute risk of empyema by 5.5–7.1% and all infectious complications by 12.1–13.4%).[17] However, we do not recommend the routine use of prophylactic antibiotics for preventing wound infection.

Local Anesthesia

A local anesthetic agent, usually lignocaine (up to a maximum dose of 3 mg/kg) is infiltrated at the site of insertion for adequate analgesia. The skin is infiltrated first followed by injection into the deeper layers. It is advisable to anesthetize a slightly wider area than the size of anticipated incision. The periosteum of the underlying ribs also needs to be anesthetized. The volume given is considered to be more important than the concentration to aid spread of the effectively anesthetized area. After infiltration of the anesthetic agent, adequate time (usually 3–5 minutes) must be given for the drug to act.

Incision and Dissection

The skin is incised parallel to and above the upper margin of the lower rib (Fig. 11C). The length of the incision is slightly larger than the diameter of the tube to be inserted and large enough to allow the operators finger to be inserted. Once the incision is made, blunt dissection of the underlying subcutaneous tissue and muscles should be done using a curved artery forceps till the pleura is reached (Fig. 11D). The pleura is punctured using the same blunt-tipped forceps. The feel of a pleural puncture is like that of a sudden give away of resistance. There will be a gush of air or of fluid the moment the pleural cavity is punctured. Next, the artery forceps should be gently opened in one direction and then again at right angles to dilate the tract, so that the chest tube can be inserted (Fig. 11E). It is important to keep the artery forceps in an open position for a few seconds to allow the tract to be adequately dilated. The creation of a patent adequately dilated track into the pleural cavity ensures that excessive force is not needed during drain insertion. The operator's finger may be used if required to explore the tract and to ensure proper placement (Fig. 11F).

Insertion of the Chest Drain

The chest tube is to be held by the artery forceps just proximal to its tip and inserted through the surgical tract (Fig. 11G). Undue force should not be used during insertion of the chest tube so as to avoid damage to the internal organs. If there is resistance during insertion, the chest tube should be removed and the tract explored and dilated using the curved artery forceps. The artery forceps should be used to ensure the entry of the tip of the chest tube into the pleural cavity and should be withdrawn thereafter (Figs 11H and I). An appropriate length of the chest tube can now be pushed inside in the desired direction. It was earlier postulated that the tip of the tube should be aimed apically to drain air and basally for fluid. However, successful drainage of air as well as fluid can be achieved with the drain in any position. The length of tube to be pushed inside will vary according to the patient's body habitus. Once the tube is inserted, the outer end of the chest tube should be cut and attached to the underwater seal bag (Fig. 11J). The proper positioning of the chest drain in the pleural cavity is confirmed by the movement of the water column in the water seal bag. The physician or assistant's left hand should press the site of insertion of the chest tube with a gauze piece so as to prevent peritubal leak of pleural fluid or air entering the pleural cavity till the tube is secured.

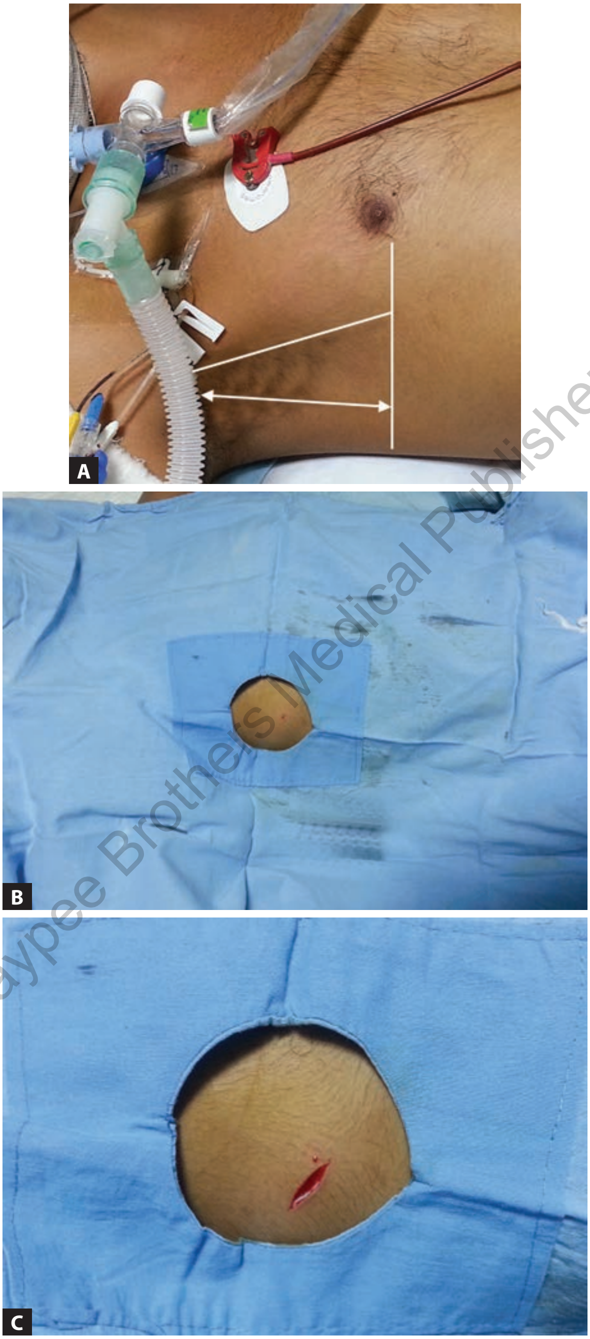
Securing the Chest Drain

The incision should be closed using one stay suture placed across at right angles to the incision (Fig. 11K). An inadvertently placed large incision may need two sutures placed across the incision. The chosen suture should be stout and nonabsorbable (silk) to prevent breakdown, and adequate depth of skin and subcutaneous tissue should be included in the suture to ensure that it is secure. The chest drain should be secured to the chest wall with the same suture which was used to close the incision using figure of 8 knots (Figs 11L and M). This is to prevent the tube from accidentally slipping out. Care should be taken to make the site of entry air tight so as to avoid any peritubal leak. Complicated "purse string" sutures must not be used to secure the chest drain as they convert a linear wound into a circular one that is painful for the patient and may leave an unsightly scar. The site of insertion of the chest tube is once again cleaned, covered with a sterile piece of gauze and an adhesive tape applied after drying the skin (Fig. 11N). Large amounts of tape and padding to dress the site are unnecessary and may restrict chest wall movement or increase moisture collection. An "omental" tag of tape may also be applied which allows the tube to lie a little away from the chest wall to prevent tube kinking and tension at the insertion site (Fig. 11O).

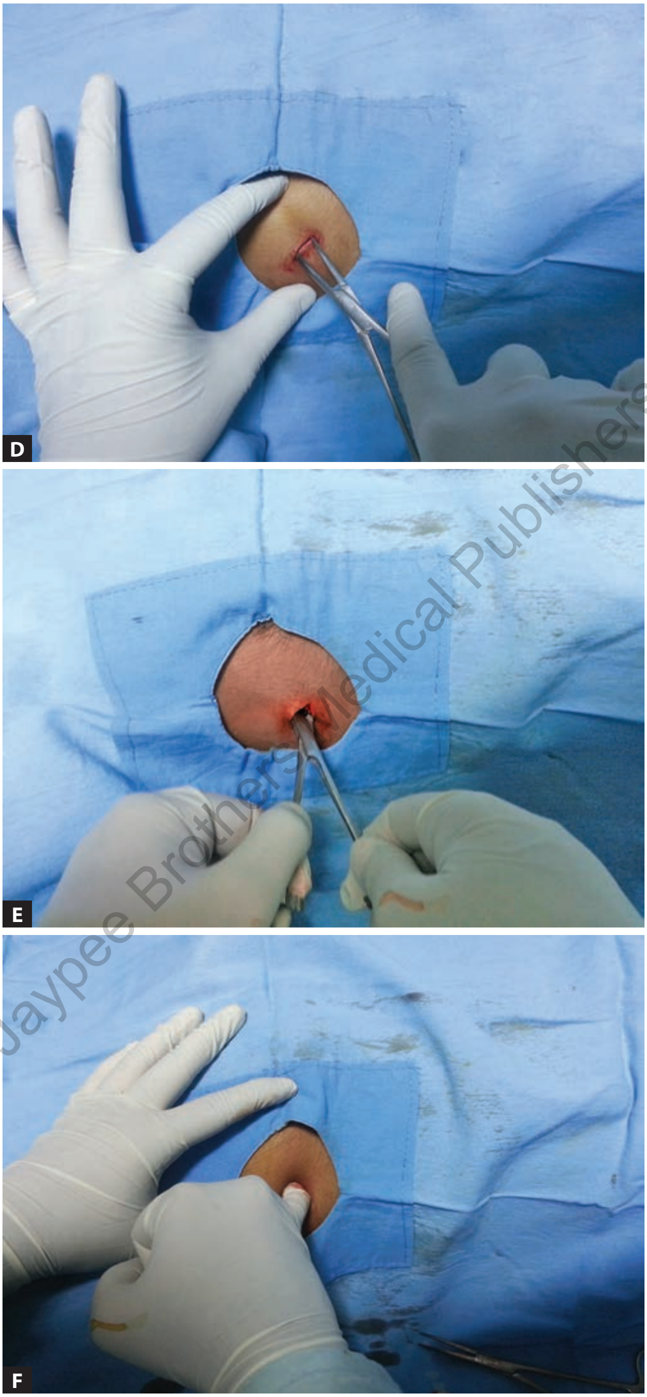
Guidewire Tube Thoracostomy

All the steps till infiltration of local anesthesia are same as that described for operative tube thoracostomy. However, premedication with a benzodiazepine or opioid is not always necessary as it is a less painful technique. The site of insertion is confirmed using an ultrasound.

- A needle attached to a syringe is introduced into the pleural cavity at the identified site. Fluid or air is aspirated to confirm the intrapleural location.
- The syringe is then removed and a 'J' tipped guidewire is introduced into the pleural cavity through the needle. This needle also is finally removed leaving the guidewire in position.

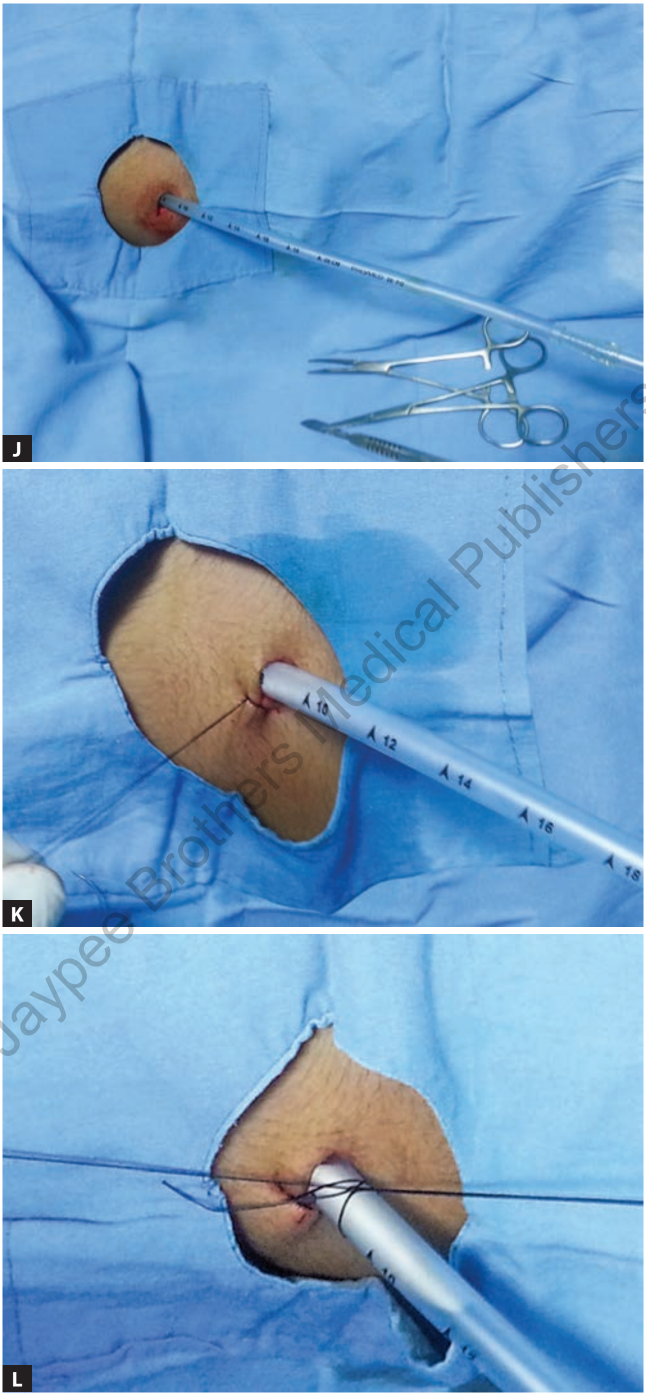


Figs 11A to C Stepwise demonstration of an intercostal drain placement by operative tube thoracostomy. (A) Identification of the site of insertion, the safe triangle; (B) Cleaning and draping. Note that a wide area is draped so as to ensure proper asepsis; (C) An incision is placed parallel to the rib margin



Figs 11D to F (D) Blunt dissection and creation of the tract being done with a blunt-tipped curved artery forceps; (E) Pleural puncture and dilation of the tract; (F) Exploration of the tract using operator's finger

Figs 11G to I (G) Insertion of the intercostal tube into the created tract. The tip of the chest tube is held with the blunt-tipped forceps and is being inserted; (H) The chest drain is held with the forceps till it is in the pleural space; (I) The forceps is then withdrawn out leaving the chest tube in the pleural space. The free end of the chest tube is now cut and the tip blocked with an artery forceps



Figs 11J to L (J) The chest tube is now attached to the underwater seal bag; (K) Placement of a linear incision closing suture; (L) The chest tube being secured to the chest wall using the same incision closing suture thread

Figs 11M to O (M) The chest tube secured using figure of 8 knots; (N) Dressing applied at the chest drain insertion site; (O) The chest drain also secured using an omental tag of tape

- A small incision is made at the guidewire entry site and the guidewire tract is then dilated sequentially using dilators of progressively increasing size. The smallest dilator is inserted first with a rotating movement until a sensation of giveaway is felt upon entry into the pleural cavity. The dilator is then removed and the next size dilator is advanced similarly over the guidewire. The guidewire should always project beyond the end of the dilator. If large bore tubes are to be inserted, a small incision or nick may be required at the site of insertion to facilitate the entry of larger dilators and the chest tube.
- The chest tube is loaded onto a stylet and is then passed into the pleural cavity over the guidewire. Once inside the pleural space, the chest tube is advanced making sure that all the side holes are in the pleural space. The stylet along with the guidewire is then removed.
- The chest tube is attached to the underwater seal and is secured to the chest wall as described above.

Trocar Tube Thoracostomy

After identifying the site of insertion, an incision is made and the skin and subcutaneous tissue dissected as described in the operative thoracostomy section. A chest tube with the trocar positioned inside the tube is used. The trocar is then inserted into the pleural space with the flat edge of the stylet cephalad. As described earlier, there is no sequential dilation and hence a considerable force would be required to puncture the pleura with the trocar. Once the pleural space is entered, the trocar is removed, leaving the chest tube inside. The tube is attached to the underwater seal bag and secured as described in the previous sections.

POST-PROCEDURE CARE

- *Confirming tube position:* The tube position should be confirmed by observing the movement of the water column in the drainage system. In a normally breathing patient, the water level will move higher on inspiration indicating a more negative pleural pressure. However in a patient on mechanical ventilation, the water level will move down with inspiration because the pleural pressure becomes more positive. A chest radiograph (both posteroanterior and lateral) should be done to confirm the position of chest tube within the pleural cavity.
- *Patient instructions:* It is of utmost importance to explain the patient about proper chest tube care. The patient should be given clear instructions (and if possible provided with a patient information leaflet) as follows: (1) To keep the chest drain upright below the insertion site at all times; (2) to avoid compression of the tube; (3) to report to medical staff immediately in case of any distress; and (4) if being discharged, daily drain output monitoring and instructions for changing the fluid in the collection system should be taught.
- *Analgesia:* All patients should be given adequate analgesia following the procedure.
- *Monitoring:* A chest drain monitoring chart should be used for all patients. The frequency of monitoring can be variable ranging from hourly to at least once a day. The parameters which need to be monitored are: (1) functionality of the tube which is assessed by movement of the water column; (2) presence

and quantification of air leak, described later in the complications section; (3) volume of drain output; (4) type of drainage with regard to color and turbidity.

- *Changing the drain fluid:* The fluid in the water seal bag should be changed at least daily and even more frequently if the drainage is excessive. The amount of fluid and also the amount of sediment collected should be noted before emptying the bag. The tube should be clamped before emptying the fluid. The fluid collected in the drainage bag should be emptied and sterile fluid (normal saline) should be filled up to the mark provided. The tube should be unclamped after changing.
- *Applying suction:* A low pressure suction (20–40 cm H_2O) may be applied if either the lung does not expand on its own or if there is a persistent air leak.
- *Chest tube dressing:* The dressing applied should be changed daily or at least once every other day. The local site should be examined for any erythema, subcutaneous emphysema, peritubal leak and pus discharge.

COMPLICATION/PROBLEM

There are various complications of tube thoracostomy ranging from minor complications not requiring any intervention to life-threatening ones.[18] It is important to understand each of these complications, strategies to prevent them and prompt identification and management once they occur.

Tube Malposition

This is the most common complication of intercostal tube drainage. Most of these occur because of failure to identify the triangle of safety of if the tube is placed during an emergency setting. Hence, it is always essential to get a chest radiograph to confirm the proper positioning of the chest tube. In two different audits performed, up to 50% of the junior doctors would have placed the chest drain outside the triangle of safety.[19,20] Tube malposition can further be classified as: (1) intraparenchymal placement; (2) intrafissural placement; and (3) extrathoracic placement (subcutaneous, mediastinum, abdomen). Intraparenchymal malpositioning usually occurs when the lung is adherent to the chest wall at the site of insertion, when undue force is used to insert the chest tube or when trocars are used without blunt dissection. It generally cannot be detected on a chest radiograph. It is identified by poor drainage and is confirmed by a computed tomography scan. The chest tube requires only to be repositioned; surgical intervention is rarely required. Intrafissural placement, though classified as a malposition, does not affect the drainage of fluid and does not need repositioning if the drain is functional. Extrathoracic subcutaneous placement is common in patients with chest trauma and in obese patients. It is identified on chest radiograph and needs repositioning. Placement into mediastinum may cause injury to heart, pulmonary artery, esophagus and nerves. Similarly, a chest tube placed too low may cause injury to abdominal organs including liver, spleen and stomach. Extrathoracic placement can also be identified at the time of insertion itself by lack of column movement. Mediastinal or abdominal organ injury needs prompt surgical correction.

Re-expansion Pulmonary Edema

This is an uncommon (0–1%) but a serious complication of tube thoracostomy. It usually occurs when chest drain is inserted for a massive pleural effusion or a large pneumothorax. Risk factors include young age (<40 years), underlying lung collapse for >7 days, large effusion or pneumothorax, rapid lung re-expansion and use of negative pressure suction. The postulated mechanism for development of this edema is increased endothelial permeability leading to exudation of a protein-rich fluid. The reason for endothelial damage is: (1) ischemia reperfusion leading to oxygen free radicals and neutrophils influx; (2) damage to the vascular endothelium in the collapsed lung due to mechanical stress; and (3) stress injury to the vascular endothelium of the normal vessels due to sudden expansion. The clinical spectrum ranges from asymptomatic radiologic finding, symptoms of chest pain, breathlessness and dry cough, to frank cardiorespiratory failure requiring mechanical ventilation and inotropic support. Re-expansion pulmonary edema can be prevented by slowly draining the massive effusion, not draining more than 1.5 liters in one setting and clamping the tube if patient develops symptoms of chest pain or dry cough. Treatment is institution of supportive measures.

Bleeding

Intercostal arteries, if injured during dissection for insertion of the chest drain, may bleed profusely. The safest zone to perform tube thoracostomy should be between 50% and 70% of the way down an interspace to avoid the variably positioned superior intercostal neurovascular bundle and the inferior collateral vessels. Systemic arteriovenous fistula (SAVF) involving an intercostal artery and subcutaneous vein can result after tube thoracostomy. The clinical manifestations of a traumatic SAVF may be immediate or delayed, ranging from 1 week to 12 years.

Subcutaneous Emphysema

This presents as a soft tissue swelling with crepitus at the site of chest drain insertion. It is usually minor and self-limited but sometimes can spread widely leading to cosmetic disfigurement and even respiratory distress. Subcutaneous emphysema develops when a side hole of chest tube is lying in the subcutaneous space or if there is obstruction of chest tube drainage system or if the drainage system cannot cope up with the air leak (Fig. 12). When extensive and correction of the above factors fail to control the emphysema, insertion of a fenestrated angiocatheter into the subcutaneous tissue (Fig. 13) or subcutaneous pigtail insertion may be required.[21]

Infectious Complications

Breach in asepsis while inserting a chest tube or in managing a chest drain leads to infectious complications. The infectious complications include empyema, surgical site infection (ranging from cellulitis to necrotizing fasciitis) and pneumonia (uncommon). Prompt identification and treatment with antibiotics is required. It is more important to prevent the development of these infectious complications.

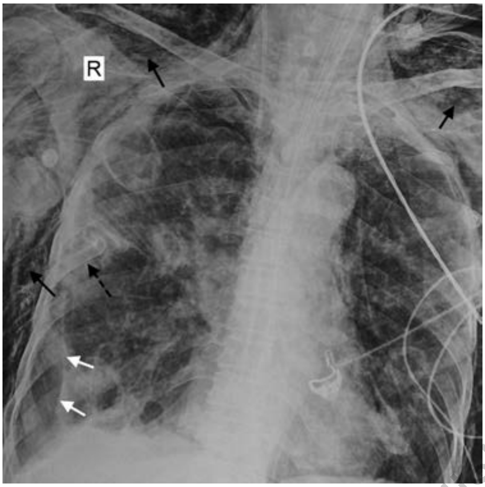


Fig. 12 Chest tube placed in the right pleural space (black dotted arrow) after the patient developed a spontaneous tension pneumothorax due to rupture of a peripheral cavity. Note the development of extensive subcutaneous emphysema (black arrows). Also note the presence of a loculated residual pneumothorax (white arrows)

Fig. 13 The subcutaneous emphysema being drained using bilaterally placed fenestrated angiocatheters (black solid arrows) connected to underwater seals (black dotted arrows)

Blocked Chest Tube

Blockade of chest drain with fibrin deposits/clots is a commonly encountered complication with the increasing use of smaller bore chest drains. It is identified by lack of movement of the water column with respiration. Milking of the chest drain is not recommended as it increases the pressures inside the pleura. Flushing the chest drain with 50 mL normal saline under sterile conditions usually restores the patency. If the cause of blockage is kinking of the chest tube, the chest drain may need to be repositioned.

Prolonged Air Leak

An air leak is defined as the presence of air bubbling in the underwater seal bag. Causes of air leak include:

- *Bronchopleural fistula:* An air leak due to a communication between a large bronchus (mainstem, lobar or segmental) and the pleural space
- *Alveolopleural fistula:* An air leak due to a communication between the pulmonary parenchyma distal to a segmental bronchus and the pleural space.
- *Peritubal leak:* An air leak due to poorly applied skin incision closing suture, which leads to air being sucked into the pleural cavity with each inspiration. The most definite way to confirm a peritubal leak is to check the $PaCO_2$ of the air coming from the chest tube. If $PaCO_2$ is less than 10 mm Hg, then it confirms a peritubal leak as the air has not participated in gas exchange.
- *System leak:* An air leak due to loose connections in the chest drainage system.

The terms alveolo- and bronchopleural fistula should not be used interchangeably as the treatment strategies differ.[22] A bronchopleural fistula usually develops only after a major pulmonary resection surgery and its management usually requires surgery. An alveolopleural fistula is the more common form of air leak that develops spontaneously or following iatrogenic trauma. Most of these heal on their own and do not need any therapeutic intervention. They also occur more commonly in mechanically ventilated patients.

There are various ways to quantify an air leak. The earliest proposed semi-quantitative and qualitative classification is the Robert David Cerfolio (RDC) classification system in which the air leak is classified as continuous (C), inspiratory (I), expiratory (E) or a forced expiratory (FE) air leak depending on the phase of respiration in which the bubbling is seen.[23] This is however highly subjective. Another semiquantitative method of classifying air leaks is by using Sahara S1100 a Pleur-evac drainage bag. The air leak is quantified on a scale from 1 to 7. A number 1 leak indicates a small leak and a number 7 leak indicates a large air leak.[24] The latest and more accurate quantitative estimation of air leaks is using digital air leak monitoring meters. The air leak is quantified in mL/min. The commercially available systems are the Thopaz and Atmos pleural drainage systems.[25]

An air leak is common after the insertion of chest drain. After a system leak and a peritubal leak are ruled out, a period of observation is all that is required in most cases. If the air leak does not heal by 5 days (ACCP Delphi statement), a thoracoscopic procedure or thoracotomy might be needed. Other techniques include blood patch pleurodesis or endobronchial management (valves or glue insertion). It has also been shown that chest drains can also be removed safely even in the presence of a persistent minor air leak as long as there is no symptomatic pneumothorax after provocative clamping.[26] If an air leak develops in a mechanically ventilated patient, the patient should be shifted to a pressure-controlled mode of ventilation and patient ventilated with the minimum possible pressures needed.

Failure of Lung Expansion

Failure of the lung to expand despite a functional and properly placed chest drain is a commonly encountered clinical scenario.[27,28] The common causes of a nonexpanding lung include:

- *Lung entrapment:* A lung is said to be entrapped when an inflammatory visceral pleural peel resulting from an active pleural process prevents the

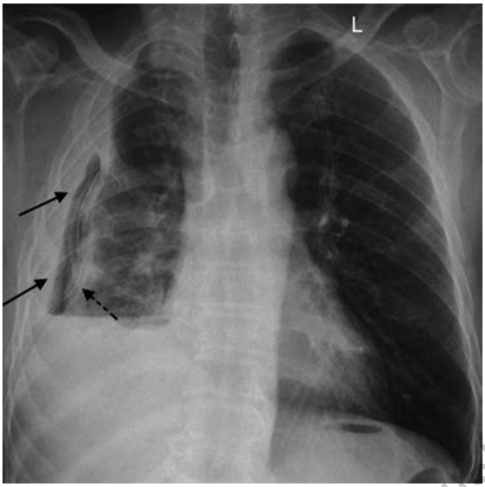


Fig. 14 Non-expanding lung after placing a chest tube (black dotted arrow) due to the presence of thick pleural peel (black solid arrows). This patient was later managed with surgical lung decortication

lung from expanding. The common causes include active pleural infection, malignancy and inflammatory diseases like rheumatoid arthritis. The pleural fluid is exudative in character and treatment of the underlying disease usually results in lung re-expansion.

- *Trapped lung:* Trapped lung is the development of a mature, fibrous pleural membrane as a sequel of remote pleural space inflammation that impedes lung expansion during fluid removal. The pleural fluid is usually a transudate and management requires decortication (Fig. 14).
- Endobronchial obstruction
- *Chronic atelectasis:* In patients with chronic atelectasis, the lung may take longer time than usual to expand unless a significant amount of parenchymal fibrosis has already set in.
- Persistent alveolopleural or bronchopleural fistula
- *Peritubal leak:* This leads to air being sucked into the pleural space with each inspiration.

Treatment depends on identification of the cause and institution of appropriate treatment.

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