Understanding and Managing Tension Pneumothorax

DG Jain*, SN Gosavi**, Dhruv D Jain***

Definition

The term ‘Pneumothorax’ denotes air in the pleural space, i.e., the space between the chest wall and the lung (Fig. 1). This is a potential space and not an actual space, because the visceral and parietal layers of the pleura are held in contact by the surface tension of their moist surfaces.

In a tension pneumothorax, the intrapleural air pressure exceeds atmospheric pressure throughout expiration and often during inspiration as well. The mechanism by which a tension pneumothorax develops is probably related to some type of a one-way valve process in which the valve is open during inspiration and closed during expiration. During inspiration, owing to the action of the respiratory muscles, the pleural pressure becomes negative, and air moves from the alveoli into the pleural space. Then, during expiration, with the respiratory muscles relaxed, the pleural pressure becomes positive.

Predisposing factors

Interstitial and obstructive lung diseases.

Classification of pneumothorax

Pneumothorax is classified according to:

A. Aetiology.
B. Extent.
C. Mechanism.
D. Duration.

A. Classification by ‘Aetiology’:

i. Spontaneous pneumothorax – It is by far the commonest form of pneumothorax in clinical practice and is always secondary to pulmonary or pleural pathology. There is no obvious cause or antecedent trauma. Patients are usually in the 20–40 years age group and present with sudden, sharp chest pain, and diagnosed. In patients of chronic bronchitis and emphysema who are over 40, there is progressive destruction of alveolar walls, and thus the high intrapulmonary pressures produced by coughing result in spontaneous pneumothorax.

   a. Primary spontaneous pneumothorax

   - Occurs in apparently healthy persons due to leak of air through a weak area of the pleura. It is initiated by marked variations in intra-thoracic pressure as in the following:
     - aeroplane ascent to sub-atmospheric pressure.
     - too rapid decompression to atmospheric pressure of divers or caisson workers.
     - pilots who eject at high altitudes.

   - Is seen in smokers.

   b. Secondary spontaneous pneumothorax

   - Is seen in cases with any underlying lung conditions, e.g., COPD usually.
   - Is more serious as it further reduces the sub-optimal pulmonary function of the underlying diseased lung.

ii. Traumatic pneumothorax (non-iatrogenic) – The usual cause is direct or indirect trauma to the chest, e.g., road accidents, stab injuries, war injuries.

iii. Iatrogenic or artificial pneumothorax – Occurs as a result of any diagnostic or therapeutic procedure.

B. Classification by ‘Extent’:

i. Localised pneumothorax – When the parietal and visceral pleura have developed adhesions.
i Generalised pneumothorax – When the whole pleural cavity, i.e., hemithorax, has air.

C Classification by ‘Mechanism’:

i Open pneumothorax – When there is movement of air in and out of the pleural cavity without any hindrance. This is due to communication between the pleural space and the airways and may lead to development of a broncho-pleural fistula (BPF). But if the hole through which the air flows is small, then the intra-pleural pressure during respiration could fluctuate.

i Closed pneumothorax – When there is no movement of air, i.e., air is trapped in the pleural space because the hole through which air entered has been obliterated.

ii Valvular pneumothorax – When air is able to enter during inspiration, but is unable to exit during expiration. This type of pneumothorax becomes a medical emergency because the air pressure keeps on increasing gradually, and the lung deflates more and more, leading to pressure effects on the mediastinum and great veins. As an effect, the mediastinum is displaced and the great veins become kinked, leading to decreased venous return to the heart. This leads to increasing cardiac and respiratory embarrassment. At this stage it is usually termed a ‘tension pneumothorax’ because of the rising pressure which builds up in the pleural cavity.

D Classification by ‘Duration’:

i Acute

i Chronic

Aetiological factors

1 Common

- Iatrogenic, e.g., insertion of a central venous catheter while managing a patient in shock.
- Mediastinal emphysema
- Spontaneous (ruptured bulla)
- Trauma

2 Rare

- Broncho-pleural fistula from lung abscess or granuloma (tuberculosis)
- Fibrocystic disease of the pancreas
- Honeycomb lung
- Hyaline membrane disease
- Oxygen toxicity; Wilson-Mikity syndrome
- Perforation of the oesophagus
- Pneumonia
- Pneumoperitoneum with passage through diaphragm
- Primary or metastatic neoplasm
- Pulmonary infarction

Pathophysiology

With reference to the atmospheric pressure, the pleural space normally has negative pressure during the complete respiratory cycle. This negative pressure is created by the chest wall which tends to expand, and the lungs which tend to collapse. As such, the alveolar pressure is more than the pleural pressure. As a result, if a leak develops between an alveolus and the potential pleural space, air moves from the alveolus to the pleural space till the pressure equalises on both sides. As a consequence, the lung volume decreases, and the thoracic cavity volume increases.

A pneumothorax results in a decrease in the vital capacity as also a decrease in the RQ. A healthy person is likely to easily cope with this reduction in lung function. But in patients with underlying lung disease, the reduced vital capacity progresses to respiratory insufficiency with alveolar hypoventilation and respiratory acidosis as a result of reduced RQ, and an increase in alveolar-arterial oxygen difference (AaDO2).

Clinical manifestations of tension pneumothorax

Symptoms of pneumothorax will depend on its type and extent. Usually, the patient experiences severe pain. Often, a small pneumothorax is asymptomatic. But when there is progressive dyspnea with pain and tightness in the affected side of the chest, then the possibility of tension
pneumothorax has to be considered7. On examination, the following are present:

1. Deviation of the trachea and apex beat to the opposite side.
2. Hyper-resonance on percussion.
3. Diminished air entry.
4. “Anvil-clink” heard on tapping two coins on the chest.
5. Tinkling rales (crepitations).

All these findings are suggestive of the presence of positive intra-pleural pressure.

Many a times, it is a spontaneous pneumothorax which progresses to become a tension pneumothorax. In a hospital setting, it could occur in patients with the following:

1. Ventilatory support.
2. Cardio-pulmonary resuscitation.
3. Pneumothorax secondary to trauma or infection2.

**Striking clinical features**

1. Anxious and distressed look, restlessness with rapid laboured breathing (respiratory distress).
2. Weak, rapid pulse; and cold, clammy skin of shock as a result of increasing intra-pleural pressure which progressively impairs the venous return to the heart1.
3. Cyanosis – is unusual in the younger patients except when severe tension pneumothorax is present. But in older patients with chronic bronchitis and emphysema, cyanosis may occur even with a small pneumothorax1.
4. Profuse diaphoresis.
5. Marked tachycardia1.

Physical signs in the chest depend essentially on the degree of pulmonary collapse, and whether or not there is an associated pleural effusion. Both chest pain and dyspnea are present in about 64% patients with primary spontaneous pneumothorax. Chest pain is present in about 90% patients. It is acute in onset, and is localised to the side of the pneumothorax.

Surgical emphysema over the neck or chest wall commonly accompanies pneumothorax due to trauma or ruptured oesophagus8.

**N.B.:** Unless the condition, i.e., the tension pneumothorax is relieved swiftly, death will occur from a combination of respiratory and cardiac failure1.

**Physical findings** – are those of any large pneumothorax4.

1. In primary spontaneous pneumothorax, there is moderate tachycardia, and the vital signs are usually normal.
2. In tension pneumothorax:
   - Pulse rate > 140.
   - Hypotension.
   - Cyanosis.
   - The side of chest with pneumothorax is larger in comparison to the contralateral side.
   - Trachea is shifted to the contralateral side.
   - The intercostal spaces are widened and appear bulged-out on the affected side.
   - Movement – i.e., excursion of chest wall – is decreased on the side with pneumothorax.
   - Tactile fremitus is absent.
   - Breath sounds are absent or reduced due to diminished air entry.
   - Percussion note is hyper-resonant.
   - "Anvil clink" (produced by tapping two coins on the chest) is heard.
   - In left-sided pneumothorax, the metallic tinkle may be synchronous with cardiac contractions (‘clicking pneumothorax’).8
   - With a right-sided pneumothorax, the lower edge of liver is shifted inferiorly.

All these signs are conclusive of the presence of positive intra-pleural pressure.

3. Surgical emphysema9: Some air escapes into the tissue planes of the chest wall after most wounds of the chest – surgical or traumatic – but it is generally slight in extent and is rapidly re-absorbed. It differs in no respect from mediastinal emphysema, and should it increase, it demands intrathoracic exploration, as a penetrating
wound of a bronchus or the trachea could be present.

**ECG changes**

In spontaneous left-sided pneumothorax:
- Rightward shift of frontal QRS axis.
- Diminution of precordial R voltage.
- Decrease in QRS amplitude.
- Precordial T-wave inversion.

These changes should not be mistaken for an acute subendocardial myocardial infarction.

**Radiological appearances**

On a roentgenogram of the chest, a pneumothorax is classically seen as an area of ‘absent’ lung markings between the bony thoracic cage and the edge of the lung.

1. A shallow pneumothorax could be missed on a cursory viewing of the chest film, but is well seen in a film taken in full expiration, or a lateral decubitus film with the affected side uppermost.

2. In a major collapse, the lung appears as a globular mass at the hilum, the density proportional to the degree of collapse, and there may be mediastinal shift to the opposite side. A tension pneumothorax usually displaces the mediastinum to the opposite side. A major degree of collapse of one lung usually results in increased blood flow and congestion in the other with appearances which may simulate lobular pneumonia.

3. Recognition of a tension pneumothorax is usually easy because of the marked compression of the lung. The lung tends to retain its shape in pneumothorax due to its elastic recoil and to traction by the pulmonary ligament. High pressure pneumothorax secondary to valve-like communication with the lung or through the chest wall often overcomes this tendency, squeezing the lung into a formless shadow along the spine, and often displacing it along the midline. The high pressure sometimes inverts the diaphragm.

4. A pleural effusion along with a pneumothorax on the same side is seen as an opacity with a horizontal upper edge; sometimes this may appear as just a blunting of the costo-phrenic angle.

5. Usually, presence of air in the thorax is clearly seen on the chest film, but it needs to be differentiated from a distended lung cyst in which reticulae are seen across the air shadow.

**Fig. 1:** Chest Roentgenogram showing left-sided pneumothorax pushing the trachea and heart towards the right.

**Diagnosis**

Early recognition of tension pneumothorax is very important because an emergency thoracentesis is the only treatment and is life-saving. It is not wise to waste precious minutes in waiting for a radiological confirmation, because the clinical presentation and physical findings are quite sufficient to establish the diagnosis. If there is any doubt, and the patient is hypoxic, it is necessary to administer supplemental oxygen.

Always remember, the diagnosis of tension pneumothorax should be suspected in:

1. Patients receiving mechanical ventilation.
2. Those patients who have a pneumothorax.
3 Patients whose condition suddenly deteriorates after a procedure known to cause a pneumothorax.
4 Patients in whom difficulty is encountered in mechanical ventilation during cardio-pulmonary resuscitation.

Clinical confirmation of diagnosis

Take a large bore needle. Attach it to a three-way stopcock which is in turn attached to a 50 ml syringe which is partially filled with sterile normal saline solution. Now, insert the needle into the pleural space through the second anterior intercostal space and withdraw the plunger from the syringe. In case of tension pneumothorax, air will immediately rush outward through the fluid in the syringe.

If a tension pneumothorax is confirmed, the needle should be left in place and in communication with the atmosphere until air ceases to exit from the syringe. Additional air can be withdrawn from the pleural space with the syringe and the three-way stopcock. However, preparations should be made for the insertion of a chest tube immediately.

If no bubbles escape from the syringe, then the patient does not have a tension pneumothorax, and the needle should be withdrawn from the pleural space.

Differential diagnosis

1 The sudden onset of chest pain and dyspnoea may simulate:
   - Myocardial infarction.
   - Pulmonary embolism.
   - Pulmonary infarction.
   - Perforated peptic ulcer.
2 Extensive bullous emphysema ("vanishing lung").
3 Pneumomediastinum.
4 Pneumopericardium.

To clinch the definitive diagnosis of pneumothorax, a lateral decubitus chest film with the affected lung uppermost is mandatory. Practically, even minute amounts of air can be seen in such a film.

Treatment

Treatment depends on the size of the pneumothorax. If small, observation is sufficient; if large, closed drainage with a chest tube is necessary.

Principles of management:

1 Maintenance of a clear airway.
2 Maintenance of adequate ventilation.
3 Oxygen therapy.
4 Treatment of the cause, i.e., removal of air from the pneumothorax.
5 Use of controlled ventilation: If, inspite of treatment, ventilation remains inadequate, the use of controlled ventilation — either through an endotracheal tube or a tracheostomy — becomes necessary.

The goal of treatment:

1 To evacuate air from the pleural space.
2 To initiate steps to prevent recurrence.

When there is no communication between the pleural space and the lung/airways, then air is reabsorbed at a rate of 1.25% of the total radiographic volume of the hemithorax per day. Thus, a 50% collapse of the lung will take 40 days to re-absorb completely once the pneumothorax is closed, i.e., no air leak persists.

Treatment options

1 A small or shallow pneumothorax — less than 20% collapse — can usually be left to absorb spontaneously; this takes about a month. A few days of rest or limitation of activity for manual workers is all that is required, and it will absorb progressively.

2 Any type of large pneumothorax — more than 20 per cent collapse and accompanied by dyspnoea — needs to be aspirated using a suitable gauge needle, a large syringe, and a two-way tap. Sometimes an artificial pneumothorax refill apparatus is also used so as to bring the intra-pleural pressure to minus 5 to minus 15 cm. H₂O. This type of aspiration can be repeated as and when required.
3 In the presence of a continual leak. A plastic or rubber catheter is inserted anteriorly in the second intercostal space approximately 5 cm. from the sternal border. The catheter is to be connected to an underwater-seal bottle. This helps evacuate the air and initiate a local irritative pleurisy. Under local anaesthesia, a self-retaining catheter of the Malecot type (size 22-28) stretched on an introducer is inserted through a cannula in the 4th or 5th intercostal space just behind the anterior axillary line, provided there are no adhesions to the chest wall in this site. Lateral pleural adhesions and persistence of an apical pneumothorax may require insertion of the catheter in the anterior chest wall, usually in the second intercostal space. The intercostal tube is usually left in situ for 24 hours after full re-expansion of the lung has been achieved, i.e., a total period of 3 - 4 days in most cases. A tube in the chest is quite painful and analgesics are necessary — if there are no contraindications like asthma, severe bronchitis, or emphysema — to make the patient comfortable.

4 In a case of tension pneumothorax. Here, the leak in the lung is valvular. Therefore, a positive air pressure may build-up in the pneumothorax so that the heart and mediastinum are progressively displaced to the opposite side, and the patient becomes increasingly breathless and cyanotic. The condition is instantly relieved in emergency by insertion into the pleural cavity, of a blunt ended, wide-bore needle — or any needle available — connected to underwater drainage or to a finger cot slit so that it acts as a one-way valve or safety valve and should be followed as soon as possible by the removal of all the air. If the valvular mechanism continues to function, the tension element will recur and the needle must then be replaced with either an indwelling needle of the Foster-Carter type, or by an intercostal catheter (Malecot type), connected to a water-sealed suction (Fig. 2) until the lung re-expands and seals off the leak.

5 When there is a large air leak and aspiration proves inadequate. Here, a thoracotomy with suturing of the damaged lung/bronchus is necessary.

N.B. In all cases where a chest tube has been inserted, the rule of thumb is that the tube should not be removed till bubbling in the underwater-seal bottle is absent on coughing, and the lung has re-expanded. Also, the tube should not be left in one position for more than seven days. But if the tube is still required, it should be replaced through a new puncture 2 cm. away.

Tube thoracostomy

Nearly every patient with a secondary spontaneous pneumothorax should initially be managed by tube thoracostomy. Even if the pneumothorax is small, its evacuation can lead to a rapid improvement in symptoms. Arterial blood gases (ABG) usually improve within 24 hours of instituting tube thoracostomy.

If the patient has respiratory failure necessitating mechanical ventilation, a chest tube should definitely be placed because the pneumothorax is likely to enlarge during mechanical ventilation. Tube thoracostomy is less efficacious in secondary than in primary pneumothorax, however. In primary spontaneous pneumothorax, the lung usually expands, and the air leak ceases within 3 days. In secondary spontaneous pneumothorax due to chronic obstructive lung disease, the mean time for the lung to re-expand is 5 days.

Open thoracotomy

When spontaneous pneumothorax is due to rupture of an emphysematous bulla, then open thoracotomy is resorted to and the bulla is surgically removed.

Pneumothorax in patients on mechanical ventilation

The development of a tension pneumothorax can be life-threatening during mechanical ventilation, since with each breath the pressure within the pneumothorax becomes greater, compromising both ventilatory and cardiovascular function.

Most clinicians are familiar with the signs of tension pneumothorax during volume ventilation because of the continually increasing PIP (peak inspiratory pressure). With pressure ventilation, the changes could be imperceptible. Since PIP is constant, VT (tidal volume) decreases as the pneumothorax increases, but its decrease is limited by the eventual equilibration of pressure in the thorax and in the
airway. That is, the pneumothorax may not extend to the degree seen with volume ventilation. With pressure ventilation, the first indication that a problem has occurred is frequently a deterioration in blood gases. With volume ventilation, the effects of a tension pneumothorax are immediate, dramatic, and usually rapidly recognised. However, with pressure ventilation, the response is less dramatic and more difficult to recognise. Careful monitoring of the patient’s physical condition, blood gases data, and chest x-rays is needed to identify a pneumothorax.

Recurrence

Recurrences are frequent and the onset of pneumothorax is unpredictable. About 20 per cent of cases of spontaneous pneumothorax recur, most of them within a year. A few cases become chronic, i.e., persisting for 3 months or longer, because of the development of a broncho-pleural fistula (BPFL).

Prevention of recurrence

Prevention is important since recurrences could seriously affect the quality of life of a patient and even endanger it. In cases where recurrences have occurred more than three times, it is advisable to go in for pleurodesis, i.e., adhering the lung to the chest wall by artificial means. For this, there are two methods:

1. Surgical:
   a. A trusted method is to do a pleurectomy wherein the parietal pleura is peeled off. Thereafter, all lung cysts which are larger than a marble are excised and sutured at the base.
   b. If the leak from the lung is large and treatment with an intercostal tube is not effective, then a thoracotomy is done with the objective of suturing or excising the ruptured cyst. In some cases a lobectomy is necessitated.

2. Medical: This method is resorted to in cases of obstinate pneumothorax. It is effected by instillation into the pleural cavity of an irritant substance which induces a bland pleurisy and subsequent pleural adhesions. Here, silver nitrate and poudrage (iodised talc or kaolin) are used for pleurodesis. However, silver nitrate has been found to be very painful. Though poudrage is also painful, it is preferred by some as the treatment of choice in cases of recurrent pneumothorax. The distribution of the talc or kaolin over the pleural surfaces is carried out visually at thoracoscopy under general

Fig. 2: A water-sealed drainage bottle. The intrapleural drainage tube is carried down under a measured quantity of saline or antiseptic solution and the negative pressure within the chest causes the fluid to rise up the tube in a meniscus which sways with respiration. The open-ended tube may be connected with a suction pump. (Adapted from Flavel G. Pulmonary Resections. An Introduction to Chest Surgery, London, Oxford University Press, 1957.)
anaesthesia. In most cases, a first or second recurrence on the same side is treated by a further intercostal tube.

Complications

1. Haemothorax.
2. Cardiovascular compromise secondary to tension pneumothorax.

Treatment of other complications

1. Severe bleeding into the pleural space may occur due to:
   a. Traumatic pneumothorax.
   b. Spontaneous pneumothorax due to rupture of a pleural adhesion (haemopneumothorax).

   This is managed by an emergency thoracotomy to evacuate the clot and to secure the source of bleeding. Blood transfusion also could be required.

2. Infection of the pleural space caused by traumatic pneumothorax or spontaneous pneumothorax may lead to empyema (pyopneumothorax). Infection could be tuberculous or non-tuberculous, e.g., staphylococcal infection. This is treated by immediate aspiration of the effusion and the institution of appropriate chemotherapy.

3. Atelectasis may complicate any type of pneumothorax and also delays expansion of the lung. This is managed by:
   a. Physiotherapy, which helps remove viscid secretions.
   b. Bronchoscopy and distension of the collapsed lobe with positive pressure using a cuffed endotracheal tube.
   c. Antibiotic cover is necessary because a collapsed lobe will certainly become bronchiectatic if it is not re-expanded, and so long as collapse persists, antibiotic cover must be continued.

4. Respiratory failure could occur in those patients whose respiratory reserve was impaired before the development of pneumothorax. The best option to treat this is to effect a rapid re-expansion of the lung.

5. Surgical emphysema: This could be produced by a rib end penetrating the pleura and damaging the lung. If the pleural cavity is non-adherent, a pneumothorax will develop and air can escape through the torn pleura into the tissues around the fracture and so up the muscle planes of the chest wall, on to the neck, face, arms, abdomen, scrotum, and legs. The eyelids close and the appearance of the patient is grotesque. The fine, silky crepitus of air in the tissues is easily recognisable to the touch and is tender. Treatment is that of the underlying pneumothorax. The air can be milked out of the tissues by squeezing it towards needles inserted in the subcutaneous tissues. This complication is frightening both to the patient and the relatives, but provided the cause is treated, is not serious and reassurance should be given.

Follow-up

It is necessary to follow-up all cases of pneumothorax for at least one year with X-rays taken every three months.

References

9. Fleischner FG. Atypical arrangement of free pleural...


Diamicron MR