ORIGINAL ARTICLE

Pneumothorax can be spontaneous, traumatic or iatrogenic. Pneumothorax ex vacuo, *sports-related pneumothorax and barotrauma unrelated to mechanical ventilation are interesting and newer entities. Management consists of getting rid of the air and prevention of recurrence of pneumothorax.*

Management of Pneumothorax and Barotrauma: Current Concepts

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INTRODUCTION

Pneumothorax, the accumulation of air in the pleural space, results from a break in the visceral or parietal pleura. Pulmonary barotrauma is a term used to describe the accumulation of extraalveolar air due to the rupture of alveoli as a result of increased intraalveolar pressure. Most commonly, this occurs in patients who are on mechanical ventilation, but pulmonary barotrauma has also been described in nonventilated patients.

The classification given in the Table 1 combines the circumstances of occurrence of pneumothorax, the etiological factors, and the state of the underlying lung. When pneumothorax occurs without trauma and is not iatrogenically induced, it is termed a spontaneous pneumothorax. A spontaneous pneumothorax occurring in an otherwise healthy person is called primary spontaneous pneumothorax. A secondary spontaneous pneumothorax occurs in patients with a variety of underlying lung diseases. Other interesting categories of spontaneous pneumothorax are catamenial pneumothorax, pneumothoraces in drug addicts and acquired immunodeficiency syndrome (AIDS) patients, familial spontaneous pneumothorax, occult pneumothorax, pneumothorax *ex vacuo*, and sports-related pneumothorax. Although this discussion will focus mainly on the management of pneumothorax, some of the recently recognized and more interesting entities will be discussed briefly.

SOME INTERESTING AND NEWLY DESCRIBED TYPES OF PNEUMOTHORACES

Pneumothorax in Drug-Abusers. When the peripheral veins of a chronic drug abuser become

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TABLE 1

Classification of Pneumothorax and Barotrauma

Spontaneous pneumothorax
- Primary
- Secondary to underlying lung disease
- Catamenial pneumothorax
- In drug addicts
- In AIDS patients
- Familial spontaneous pneumothorax

Traumatic pneumothorax

Iatrogenic pneumothorax
- Barotrauma and pneumothorax associated with mechanical ventilation
- Accidental
  - *During diagnostic procedures:* transbronchial lung biopsy and aspiration, subclavian vein catheterization, thoracentesis, electrophysiologic testing
  - *During therapeutic procedures:* CPR, tracheostomy, pulmonary function testing, acupuncture, incorrect position of nasogastric tube, secondary to radiation and chemotherapy, during laparoscopic cholecystectomy, hyperbaric oxygenˆ

Special situations
- Pneumothorax *ex vacuo*
- Sports related pneumothorax
- Barotrauma unrelated to mechanical ventilation
- Postoperative air spaces
- Barotrauma in airplane passengers, pilots, divers and other causes of barotrauma
- Spontaneous pneumothorax following contralateral pneumonectomy
- Spontaneous pneumothorax in pregnancy

AIDS, acquired immunodeficiency syndrome; CPR, cardiopulmonary resuscitation.

obliterated because of a sclerotic or infectious process, an IV drug abuser may attempt to use larger veins in the groin or neck. Attempted subclavicular or supraclavicular injection ("pocket shoot") of drugs in the street setting has led to unilateral or bilateral pneumothoraces.[1-5] Douglass and Levison[5] found that the incidence is equal in both sexes and that it is less of a problem in teenagers.

Although most drug users describe using small (21- or 22-gauge) needles, a large, complete or a tension pneumothorax usually develops, often bilaterally.[1-3] Prophylactic antibiotics are usually necessary.

Pneumothorax in AIDS Patients. Spontaneous pneumothorax in patients with AIDS has become the leading cause of nontraumatic pneumothorax in the population.[6] With the diagnosis of AIDS, a patient's risk of sustaining a nontraumatic pneumothorax increases to 450 times that of general population.[7] A high incidence (2% to 9%) has been reported in patients with AIDS and *Pneumocystis carinii* pneumonia,[8-10] especially those on prophylactic aerosolized pentamidine.[8,11] Mechanical ventilation and bronchoscopy are often required in AIDS patients, further increasing their risk of pneumothorax.[12,13] The pneumothorax is frequently bilateral, recurrent, and not responsive to conservative therapy.[14,15]

Traumatic Pneumothorax. Traumatic pneumothorax most often occurs as a result of penetrating injury but may also occur with closed chest trauma consequent to alveolar rupture from thoracic compression, fracture of a bronchus, esophageal rupture, or rib fractures that lacerate the pleura.[16,17] Traumatic pneumothorax can be subclassified into open, closed, tension, or hemopneumothorax.

Occult Pneumothorax. Increasing use of computed tomography (CT) scanning for the evaluation of blunt abdominal trauma has revealed a new diagnostic entity described as "occult pneumothorax".[18-23] In a series of 67 trauma patients, Hill et al.[24] reported 71 pneumothoraces found on CT, which were not seen on admission chest radiograph. The management of occult pneumothoraces is controversial. Wolfman et al.,[25] reporting on 44 occult pneumothoraces, suggested that most small (miniscule) occult pneumothoraces and moderate-sized pneumothoraces in asymptomatic, nonmechanically ventilated patients can be managed by observation. However, most anterolateral pneumothoraces will require chest tube placement.

Iatrogenic Pneumothorax. The leading causes of iatrogenic pneumothorax are transthoracic needle aspiration (24%–36%), subclavian venepuncture (22%–23%), and thoracentesis (20%–31%). Positive pressure ventilation has been reported to be the causative factor in only 7% of all iatrogenic pneumothoraces. Most patients require treatment for 4 to 7 days and hospitalization is rarely prolonged due to this complication.[26,27]

Barotrauma and Pneumothorax in Mechanically Ventilated Patients. One of the important complications of mechanical ventilation is barotrauma. In one of the series,[28] 15 of 430 patients receiving ventilatory support for longer than 12 hours developed pneumothorax. Risk factors include high inflation pressures and inflation volumes, positive end-expiratory pressure, and diffuse lung injury.[29] Petersen and Baier[30] reported a 43% incidence of barotrauma in patients who required a peak airway pressure above 70 cm H_2O.

An early radiologic feature and a harbinger of life-threatening barotrauma is the presence of pulmonary interstitial emphysema. Pulmonary interstitial emphysema manifests radiologically as small parenchymal cysts, circular cuffs around larger pulmonary vessels projected end-on (perivascular halos), small dots representing small peripheral vessels surrounded by areas of radiolucency, linear streaks of air radiating toward the hilum, large cystic collections of air, and subpleural air.[31,32] (Figure 1A) The air, having entered the interstitium, then dissects proximally along bronchovascular sheaths towards the lung hilum and mediastinum. Once in the mediastinum, the accumulated air takes the path of least resistance and may produce subcutaneous emphysema, pneumopericardium (Figure 1B), or pneumoperitoneum. If the mediastinal pressure rises abruptly or if decompression via these routes is not sufficient, the parietal pleura may rupture, resulting in pneumothorax. However, recent studies[33, 34] have shown that the incidence of barotrauma is independent of airway pressure. It is now accepted that pulmonary edema and lung injury during mechanical ventilation are the consequence of "volutrauma" rather than "barotrauma".[35] In a recently published study by 'The Acute Respiratory Distress Syndrome Network', it was found that treatment with a ventilator strategy designed to protect the lungs from excessive stretch resulted in decreased mortality and increased the number of days without ventilator use in patients with acute lung injury and acute respiratory distress syndrome.[36]

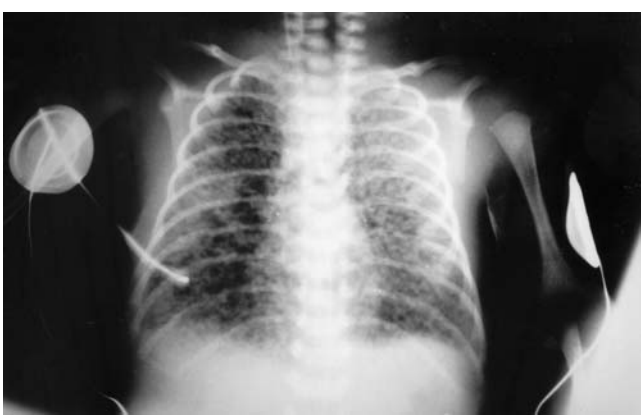

Figure 1A.—A preterm infant with respiratory distress syndrome. The roentgenogram shows cysts and linear streaks of air, the signs of pulmonary interstitial emphysema.

Pneumothorax After Fiberoptic Bronchoscopy, Needle Biopsy of the Lung and Thoracentesis. Milam et al.[37] found that, after transbronchial biopsy, the rate of pneumothorax was 1.9% and concluded that in fiberoptic bronchoscopy without transbronchial biopsy, an immediate postbronchoscopy roentgenogram is not necessary. Pneumothorax after bronchoalveolar lavage without biopsy and after transbronchial needle aspiration is very low.[38] The incidence of pneumothorax after percutaneous needle biopsy[39,40] is much higher and ranges from 17% to 43%.

Raptopoulos et al.[41] found that ultrasonographically-guided thoracentesis, use of the smallest possible needle, and aspiration of the smallest possible amount of fluid are complicated by pneumothorax significantly less often than thoracentesis done using conventional techniques. Age, sex, underlying lung condition, overall clinical condition, size of the effusion, and type of tap (diagnostic or therapeutic) had no significant effect on the occurrence of pneu-

Figure 1B.—Roentgenogram of the same infant as in Fig. 1A, who went on to develop pneumopericardium.

mothorax after thoracentesis. In asymptomatic patients, the likelihood of detecting pneumothorax is so low that the practice of obtaining a routine chest radiograph may not be justified.[42]

Pneumothorax Due to Nasogastric Feeding Tubes. Narrow bore feeding tubes are particularly likely to give rise to the complication of pneumothorax because of their small diameter (2.7 mm), self-lubricating properties, and wire stylet, all of which permit their undetected entry into the tracheobronchial tree, perforation of pulmonary tissue, and lodging in the pleural cavity.[43] Other factors associated with increased risk of misplacement of feeding tube include: the presence of an endotracheal or tracheostomy tube (these may favor pulmonary passage of the tube by preventing glottis closure and perhaps by inhibiting swallowing), altered mental status, denervation of airways, esophageal stricture, enlargement of the heart, and neuromuscular weakness.[44] The clinical signs commonly used to ascertain correct placement of the feeding tube and even a radiograph may be misleading.

Special Situations. *Pneumothorax ex vacuo*. Development of pneumothorax after partial resolution of total bronchial obstruction,[45] as a complication of lobar collapse[46] and after therapeutic thoracentesis for malignant effusions[47] has been described, but is not a commonly recognized entity. In pneumothorax *ex vacuo*, acute lobar collapse results in a sudden increase in negative pleural pressure surrounding the collapsed lobe. Although the parietal and visceral pleural surfaces remain intact, the gas originating from the ambient tissues and blood is drawn into the pleural space, producing a pneumothorax. Recognition of this type of pneumothorax is crucial because the management is relief of bronchial obstruction rather than inserting a chest tube.

Sports-Related Pneumothorax. It has been recently recognized that sports-related air leaks and pneumothorax occur more frequently than the literature suggests. Levy et al.[48] and Patridge et al.[49] each described three cases of pneumothorax or pneumomediastinum caused by blunt trauma sustained during a contact sport. Kizer et al.[50] identified 20 patients who had sustained a spontaneous or traumatic air leak while engaged in an outdoor sport. These authors suggested that emergency physicians should have a high index of suspicion for this entity.

Barotrauma Unrelated to Mechanical Ventilation. Although traditionally, the term *barotrauma* has been used to describe development of extraalveolar air in a patient on mechanical ventilation, there are many other situations where, due to increased intraalveolar pressure, air leaks out of alveoli. Pulmonary barotrauma of ascent is a well-known complication of compressed air diving. Tetzlaff et al.[51] found that pre-existing small lung cysts and/or end-expiratory flow limitation may increase the risk of pulmonary barotrauma, although Neuman et al.[52] contested these conclusions. Clinically significant pulmonary barotrauma has been reported from self-inflating bag-valve devices,[53] after inflation of party balloons,[54] as a result of blast injury,[55,56] during submarine escape training,[57] after automobile airbag deployment,[58] and in a normal healthy volunteer after repeated measurements of maximal expiratory pressure.[59]

CLINICAL FEATURES

The clinical features of pneumothorax depend upon its size, the underlying lung condition, and whether the pneumothorax is tension in type. Primary pneumothorax usually develops in tall, thin males while at rest. Most often, the onset of symptoms is not related to physical exertion. Surprisingly, many patients do not seek medical attention immediately after the development of symptoms. In one series,[60] 18% of patients waited for more than 1 week after developing symptoms. Chest pain and dyspnea are the two main symptoms associated with the development of pneumothorax. Cough, malaise, orthopnea, or hemoptysis may be presenting symptoms.

Small pneumothoraces (< 25%) may not be detectable clinically, especially in an emphysematous patient. Larger pneumothoraces may produce tachycardia and tachypnea. There is usually decreased motion, hyperinflation, hyperresonance, decreased vocal resonance, and decreased breath sounds on the side of the pneumothorax. Pleural friction rub may be present. In a large pneumothorax, the trachea and apex beat may be shifted to the opposite side, and liver dullness may be masked. The presentation in tension pneumothorax is more dramatic. Due to a ball-valve mechanism, air enters the pleural cavity but cannot escape, thereby, building up a positive pressure. As the tension continues to increase, the diaphragm is flattened, the mediastinum is shifted to the opposite side, and ultimately results in cardiopulmonary collapse. (Figure 2) In left-sided pneumothorax and pneumomediastinum, systolic clicks, crunching, and whooping sounds have been described.[61,62]

The clinical features of pneumothorax in certain situations may be atypical, and the diagnosis is based on a high index of suspicion. *During a transbronchial biopsy*, a patient may complain of pleuritic

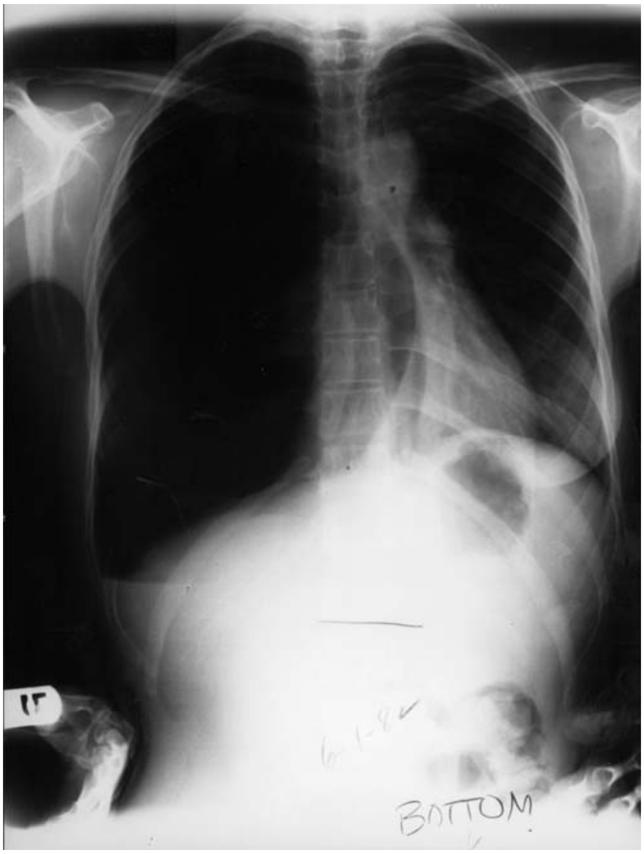

Figure 2.—Roentgenogram of a patient with tension pneumothorax showing shifting of the mediastinum to the opposite side.

pain, followed by progressive dyspnea. *After subclavian vein catheterization*, progressive dyspnea or alteration in the vital signs should alert the clinician to this complication. *In a mechanically ventilated patient*, development of pneumothorax is suspected by new onset respiratory distress, hypotension, agitation, unilateral decrease in breath sounds, worsening oxygenation, and a decrease in static and dynamic compliance.[63,64] *In sports-related pneumothorax*, pneumothorax may be difficult to recognize because athletes' physical fitness may mask their serious injury and athletes may be more inclined to downplay their symptoms.[50]

RADIOGRAPHIC SIGNS

The chest radiograph confirms the presence of pneumothorax in most of the cases. Classically, lung markings peripheral to the visceral pleural line are absent. When the film cartridge used for the portable chest radiograph is placed under the patient, skin on the back can fold over on itself to produce a line that runs down the hemithorax; this line can easily be mistaken for pneumothorax (Figure 3), although certain radiological signs can differentiate these two entities.[65]

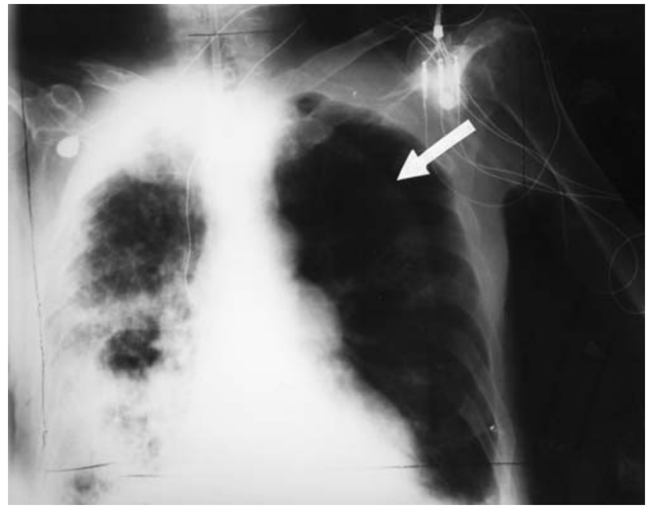

Figure 3.—Skin fold mimicking the pleural line of pneumothorax.

In the critical care setting, roentgenograms often must be obtained in the supine position. Pneumothorax has a different roentgenographic appearance in this situation. In the supine position, the following features suggest the presence of pneumothorax: "the deep sulcus sign" (Figure 4), an unusually distinct cardiac apex and pericardial fat tags, and increased hyperlucency of the upper abdominal quadrants.[66-70] Any of these findings should prompt a CT scan to establish the diagnosis of pneumothorax.

MANAGEMENT

The first step in the management of pneumothorax is to remove the air from pleural space and allow reexpansion of the lung with the least possible morbidity, followed by measures to minimize the likelihood of a recurrence. There are several different approaches; the best approach in a given patient depends upon various factors, such as the size of pneumothorax, whether the pneumothorax is primary or secondary, the condition of the lungs, the occupation of the patient, whether the pneumothorax has occurred in any special setting, and whether it is the first or a recurrent episode. New American College of Chest Physicians practice guidelines have been developed using the Delphi technique* which reflect views of 32 international experts. Many new recommendations have been made, which suggest a shift from the previous practices and are discussed later.[71]

Initial Management. *Expectant Therapy.* Kircher and Swartzel[72] estimated that 1.25% volume of pneumothorax is absorbed each 24 hours. Therefore, if a patient has a 20% pneumothorax, it will

** The Delphi technique is an approach used extensively within social sciences to gain consensus among a panel of experts in round table discussions employing structured questionnaires, appropriateness scores, and consensus scores.*

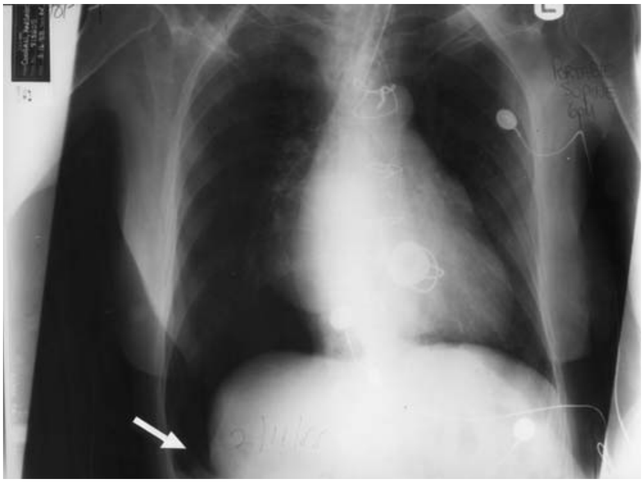

Figure 4.—The deep sulcus sign in a supine patient.

take 16 days for the air to be absorbed spontaneously. It is recommended that hospitalized patients with any type of pneumothorax who are not subjected to aspiration of air or tube thoracotomy be treated with supplemental oxygen at high concentrations, which increases the rate of absorption of air.[73]

Removal of Air From the Pleural Space. In those patients whose pneumothorax is large (> 20% to 25%), progressive or tension type; who are symptomatic; have an underlying chronic lung disease; are on a ventilator, or who have a recurrent pneumothorax, the air from the pleural space needs to be removed by various therapeutic means rather than allowed to be absorbed spontaneously. The following methods have been used for the removal of air: simple aspiration of air, tube thoracostomy, percutaneous pneumothorax catheter, and thoracic vent.

Further Management. As mentioned earlier, the initial episode of pneumothorax may be managed by simple observation or may need drainage. In the following groups of patients, further management needs to be planned after the resolution of pneumothorax: recurrent pneumothorax, patients with chronic air leak, patients with demonstrable large bullae, and patients who live in remote areas or pursue an occupation in which a recurrence could be a hazard (e.g., airline personnel or divers).[74,75] Further management in these high-risk groups is aimed at preventing recurrence. The following approaches have been used: chemical pleurodesis, surgery, and thoracoscopic surgery. These have been discussed in detail in various textbooks and review articles.[76-80]

Management Under Special Circumstances. *Pneumothorax in AIDS Patients.* In any patient with AIDS who develops pneumothorax, *Pneumocystis carinii* pneumonia should be considered and treated.[8] Patients with asymptomatic spontaneous pneumothorax can be safely observed.[12] Aggressive stepped-care management with large-bore intercostal tube drainage, chemical pleurodesis, and early videothoracoscopic talc poudrage has been recommended.[81]

Pneumothorax in Cystic Fibrosis. Pleurodesis, as an initial step in the management of pneumothorax, is considered contraindicated because it results in extensive pleural adhesions that jeopardize subsequent lung transplantation.[82] Noyes and Orenstein,[83] therefore, have recommended step-wise management of pneumothorax in cystic fibrosis. If initial tube thoracotomy does not bring resolution of air leak within 5 days, blebectomy is indicated. If blebectomy proves unsuccessful, with either continuing air leak or recurrence, a definitive pleural ablative procedure should be undertaken.

Pneumothorax in Air Travelers. Air or gas trapped in body cavities expands in direct proportion to the decrease in atmospheric pressure. At an altitude of 10,000 feet a pneumothorax will increase 1.5 times in size.[84] Therefore, if a patient with pneumothorax, especially secondary to chronic obstructive pulmonary disease, has to be transported, the following precautions should be taken: (1) the ability of the patient to take supplemental oxygen without causing alveolar hypoventilation must be established prior to the flight; (2) a chest tube with a Heimlich flutter valve should be in place; (3) it is advisable to have the patient travel with a knowledgeable companion.[85]

Persistent Pulmonary Air Leak and Bronchopleural Fistula. Conventionally, an air leak persisting for more than 7 days is called bronchopleural fistula. If the leak persists beyond 4 to 7 days, tube thoracostomy is deemed to have failed and a more definitive treatment is planned. Such cases are usually managed surgically or by chemical pleurodesis.

COMPLICATIONS RELATED TO MANAGEMENT

Unilateral reexpansion pulmonary edema and reexpansion hypotension have been recognized as complications during the management of pneumothorax. Reexpansion pulmonary edema (Figures 5A & 5B) tends to occur with greater frequency in patients 20–39 years of age, when there is complete collapse of the lung, when the pneumothorax has remained untreated for more than 72 hours, and when rapid reexpansion occurs secondary to the application of negative pressure.[86] Slow expansion by intermittent clamping of the chest tube,

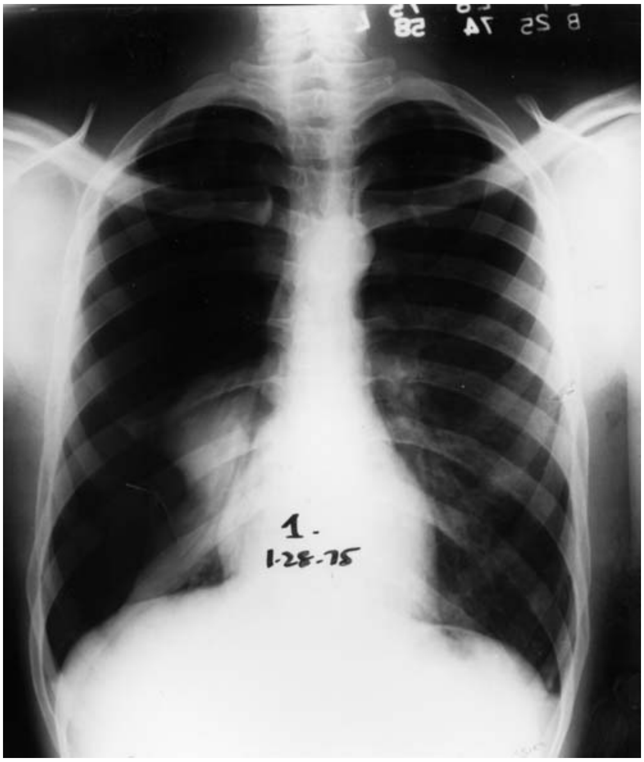

Figure 5A.—Large pneumothorax.

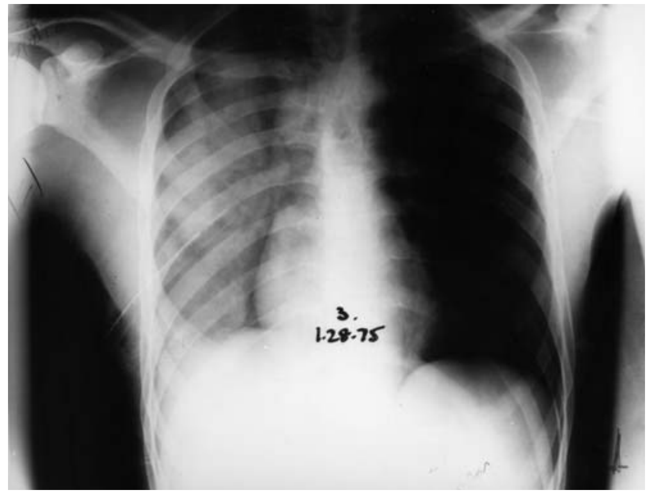

Figure 5B.—Reexpansion pulmonary edema.

especially in high-risk patients, may prevent both reexpansion edema and reexpansion hypotension.[87] Paradoxically, vigorous fluid therapy may be advantageous in preserving circulation dynamics despite the coexisting pulmonary edema.

GUIDELINES FOR THE MANAGEMENT OF PNEUMOTHORAX

A more aggressive approach to the management of pneumothorax has been advocated recently.[88] The new guidelines for management of pneumothorax, which were previewed at the 1999 Annual Meeting of the American College of Chest Physicians, reflect this trend.[89] Given below are some of the salient points, highlighting the shift from the more conventional management strategies.

A. Management of Primary Pneumothorax:
- A clinically stable patient with small pneumothorax may be managed by simple observation in emergency department for 3 to 6 hours. Chest radiograph should be done before discharge and after 12 to 48 hours.
- A clinically stable patient with large pneumothorax: admit to hospital and place a small bore chest tube with Heimlich valve or insert a chest tube. Unstable patient with a large pneumothorax: Admit and place a chest tube.
- Thoracoscopy is preferred over pleurodesis for the management of persistent leak in primary pneumothorax. Larger tubes, 24F to 28F, are preferred for patients at high risk of an air leak, whereas, small tubes, even less than 14F may be used for low-risk patients. The chest tube should be connected to a water seal; suction should be reserved for patients with persistent leak. The chest tube removal should follow a staged approach: stop suction, continue water seal, obtain a chest radiograph to confirm inflation, wait for 6 to 12 hours after the last evidence of leak before removing the tube. Thoracoscopy for prevention should be done after the second pneumothorax. Radiological evaluation should be done to detect any bullous disease, in which case, a definitive preventive management may be justified, even after the first occurence.

B. Management of Secondary Pneumothorax:
- Stable patients with small pneumothorax may be observed but must be hospitalized. Patients with large pneumothorax must be admitted and a chest tube placed. Suction should be used if lung fails to expand.
- The key difference from the management of primary pneumothorax is that 12 to 24 hours should elapse between the last evidence of an air leak and chest tube removal. Although the guidelines have suggested that thoracoscopic pleural abrasion and bullectomy should be done after the first pneumothorax, I feel that the patient should be evaluated by a CT scan and unless bullous disease is detected, the chest tube may be removed and patient observed.

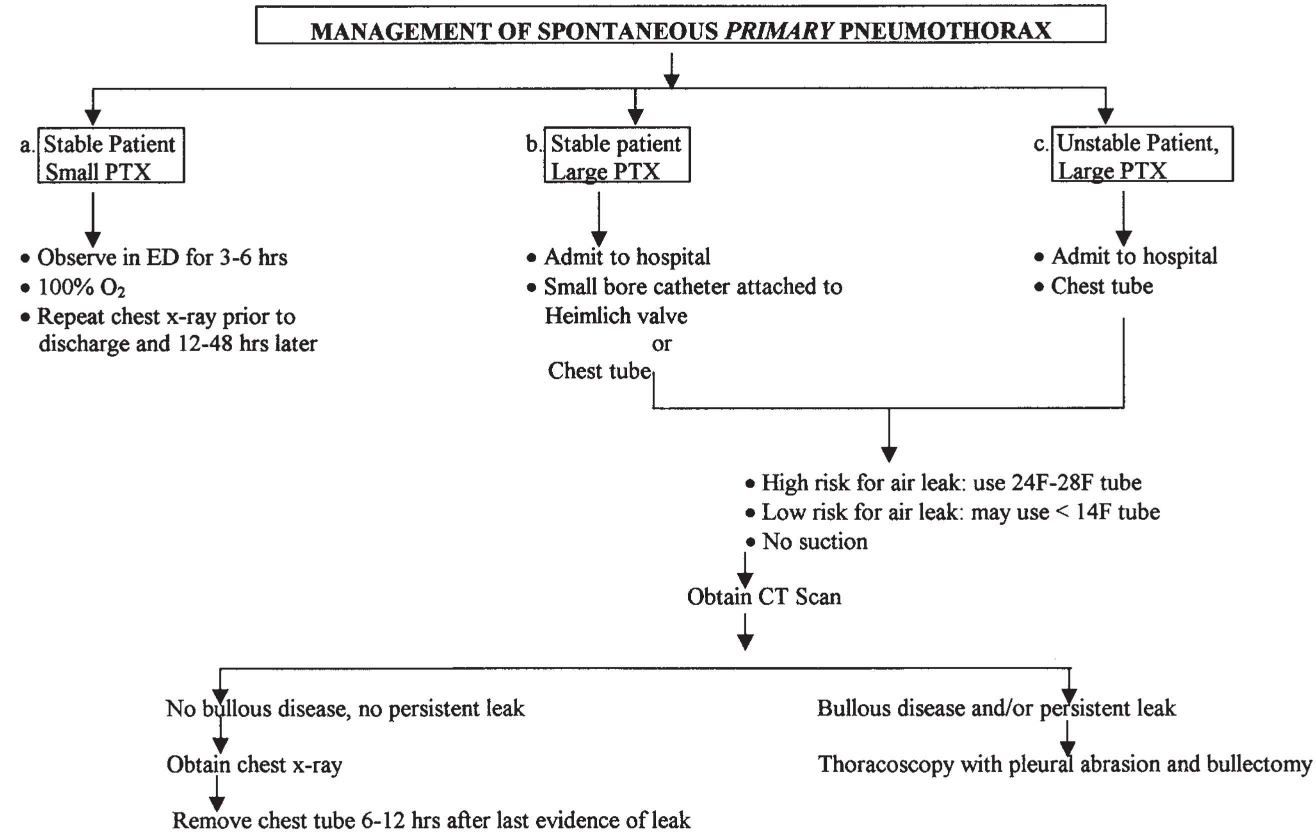

Figure 6A.—Algorithm for the management of pneumothorax. PTX, pneumothorax; ED, emergency department; CT, computed tomography.

SUMMARY

Pneumothorax is an emergency that is being seen more frequently, especially due to barotrauma in ventilated patients or after invasive procedures like insertion of central venous catheters, pulmonary artery catheterization, and bronchoscopy. Occurrence of pneumothorax in AIDS patients and drug abusers is an interesting problem. The symptoms and signs of pneumothorax may be atypical in certain situations. Radiologically, pneumothorax is easy to recognize, but a high index of suspicion is required to diagnose it in a supine patient. The goal of management is straightforward—to get rid of the air present in the pleural space—but astute clinical judgment is required to select an appropriate approach. Further management requires careful consideration of various factors. The approach suggested in Figures 6A & 6B which incorporates the American College of Chest Physicians guidelines, can be applied to most of the patients. **CT**

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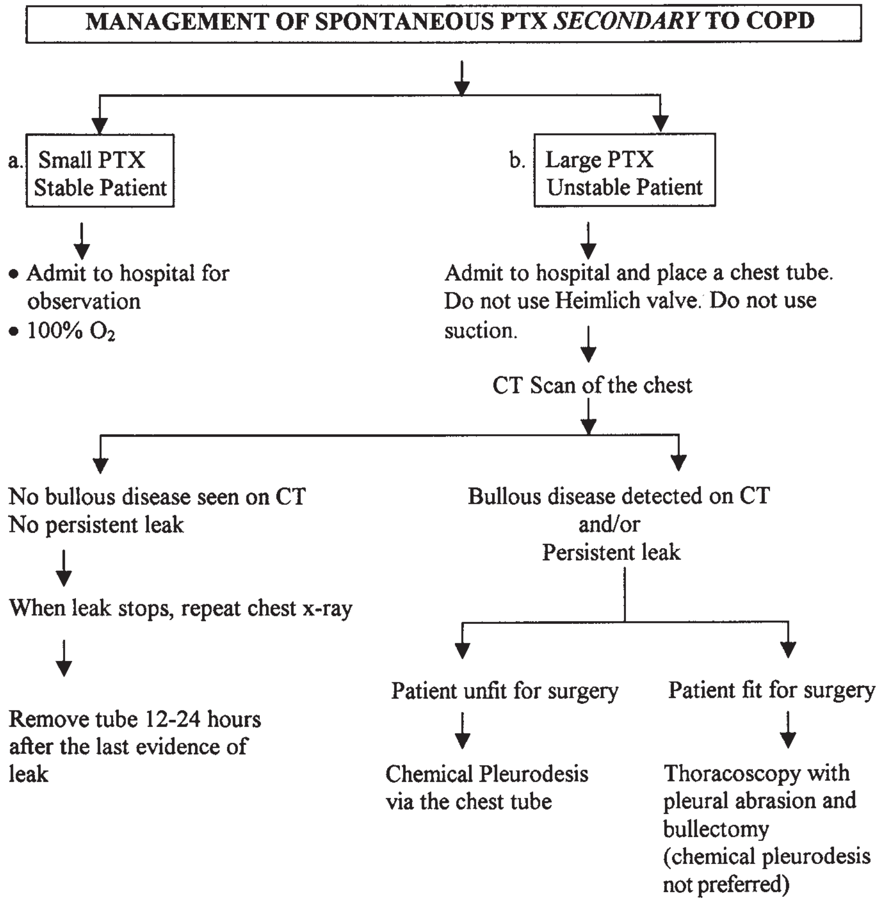

Figure 6B.—Algorithm for the management of pneumothorax. PTX, pneumothorax; CT, computed tomography; COPD, chronic obstructive pulmonary disease.

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