Primary Care

Spontaneous Pneumothorax

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PNEUMOTHORAX is classified as spontaneous (not caused by trauma or any obvious precipitating factor), traumatic, or iatrogenic (Table 1). Primary spontaneous pneumothorax occurs in persons without clinically apparent lung disease; secondary spontaneous pneumothorax is a complication of preexisting lung disease. Iatrogenic pneumothorax results from a complication of a diagnostic or therapeutic intervention. Traumatic pneumothorax is caused by penetrating or blunt trauma to the chest, with air entering the pleural space directly through the chest wall; visceral pleural penetration; or alveolar rupture due to sudden compression of the chest. In this review we focus on spontaneous pneumothorax.

PRIMARY SPONTANEOUS PNEUMOTHORAX

Epidemiology

Primary spontaneous pneumothorax has an estimated incidence of between 7.4 cases (age-adjusted incidence) and 18 cases per 100,000 population per year among men and between 1.2 cases (age-adjusted incidence) and 6 cases per 100,000 population per year among women.[1,2] It typically occurs in tall, thin boys and men between the ages of 10 and 30 years and rarely occurs in persons over the age of 40.[3] Smoking cigarettes increases the risk of primary spontaneous pneumothorax in men by as much as a factor of 20 in a dose-dependent manner.[4]

Pathophysiology

Although patients with primary spontaneous pneumothorax do not have clinically apparent lung disease, subpleural bullae are found in 76 to 100 percent of patients during video-assisted thoracoscopic surgery[5-8]

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and in virtually all patients during thoracotomy.[4,9-12] Subpleural bullae in the contralateral lung are found in 79 percent to 96 percent of patients with pneumothorax that is managed by sternotomy.[9,11] Computed tomography of the chest shows ipsilateral bullae in 89 percent of patients with primary spontaneous pneumothorax, as compared with 20 percent of controls matched for age and smoking status.[13,14] Even among nonsmokers with a history of pneumothorax, 81 percent have bullae.[15]

The mechanism of bulla formation remains speculative. A plausible explanation is that degradation of elastic fibers in the lung occurs, induced by the smoking-related influx of neutrophils and macrophages. This degradation causes an imbalance in the protease–antiprotease and oxidant–antioxidant systems.[16-18] After bullae have formed, inflammation-induced obstruction of the small airways increases alveolar pressure, resulting in an air leak into the lung interstitium. The air then moves to the hilum, causing pneumomediastinum; as mediastinal pressure rises, rupture of the mediastinal parietal pleura occurs, causing pneumothorax.[19] Histopathological analysis and electron microscopy of tissue obtained at surgery have not shown that there is a defect in the visceral pleura through which air escapes from bullae into the pleural space.[20] Most patients with pneumothorax do not have evidence of pleural effusion on standard chest radiography. The increase in pleural pressure caused by the pneumothorax inhibits the movement of interstitial liquid into the pleural space.

A large, primary spontaneous pneumothorax results in a decrease in vital capacity and an increase in the alveolar–arterial oxygen gradient, causing varying degrees of hypoxemia. Hypoxemia occurs as a result of a low ventilation–perfusion ratio and shunting, with the severity of the shunt being dependent on the size of the pneumothorax. Because the underlying lung function is normal, hypercapnia does not develop in patients with primary spontaneous pneumothorax.

Clinical Presentation

Most episodes of primary spontaneous pneumothorax occur while the patient is at rest.[21] Virtually all patients have ipsilateral pleuritic chest pain or acute dyspnea.[22] Chest pain may be minimal or severe and, at onset, has been described as "sharp" and later as a "steady ache." Symptoms usually resolve within 24 hours, even if the pneumothorax remains untreated and does not resolve.

Patients with a small pneumothorax (one involving <15 percent of the hemithorax) may have a normal physical examination. Tachycardia is the most com-

TABLE 1. CLASSIFICATION OF PNEUMOTHORAX
ACCORDING TO CAUSE.

Spontaneous
Primary: no clinical lung disease
Secondary: a complication of clinically apparent lung
   disease

Traumatic
Due to penetrating chest injury
Due to blunt chest injury

Iatrogenic
Due to transthoracic-needle aspiration
During placement of a catheter in the subclavian vein
Due to thoracentesis and pleural biopsy
Due to barotrauma

mon physical finding. In patients with a larger pneumothorax, the findings on examination may include decreased movement of the chest wall, a hyperresonant percussion note, diminished fremitus, and decreased or absent breath sounds on the affected side. Tachycardia of more than 135 beats per minute, hypotension, or cyanosis should raise the suspicion of a tension pneumothorax. The results of arterial-blood gas measurement typically indicate an increase in the alveolar–arterial oxygen gradient and acute respiratory alkalosis.

Diagnosis

The diagnosis of primary spontaneous pneumothorax is suggested by the patient's history and is confirmed by the identification of a thin, visceral pleural line (<1 mm in width) that is found to be displaced from the chest wall on a posterior–anterior chest radiograph obtained with the patient in an upright position. A radiograph obtained during expiration may help in identifying a small apical pneumothorax; however, the routine use of this type of radiography does not improve the diagnostic yield.[23]

Recurrence

In a compilation of 11 studies of primary spontaneous pneumothorax in which patients were treated with observation, needle aspiration, or drainage through a chest tube, the average rate of recurrence was 30 percent, with a range of 16 to 52 percent.[24] Most recurrences occur within six months to two years after the initial pneumothorax,[25-27] although not all studies have confirmed this interval.[28,29] Radiographic evidence of pulmonary fibrosis, asthenic habitus, a history of smoking, and younger age have been reported to be independent risk factors for recurrence.[25] In contrast, computed tomographic[13] or thoracoscopic[30] evidence of bullae during the evaluation of an initial spontaneous pneumothorax is not predictive of recurrence. Therefore, the presence of bullae by themselves should not form the basis of decisions regarding the prevention of recurrence.

SECONDARY SPONTANEOUS PNEUMOTHORAX

In contrast to the benign clinical course of a primary spontaneous pneumothorax, secondary spontaneous pneumothorax is a potentially life-threatening event, because patients with this condition have associated lung disease and limited cardiopulmonary reserve. The major causes of secondary spontaneous pneumothorax are listed in Table 2.

Chronic obstructive pulmonary disease and *Pneumocystis carinii* pneumonia related to infection with the human immunodeficiency virus (HIV) are the most common conditions associated with secondary pneumothorax. The probability of pneumothorax increases as chronic obstructive pulmonary disease worsens; patients with a forced expiratory volume in one second (FEV_1) of less than 1 liter or a ratio of FEV_1 to forced vital capacity (FVC) of less than 40 percent are at greatest risk[13] (Fig. 1). Spontaneous pneumothorax develops in 2 to 6 percent of HIV-infected patients[31] and is associated with *P. carinii* pneumonia in 80 percent of those cases.[31-33] Pneumothorax is associated with a high mortality in patients with HIV infection who have *P. carinii* pneumonia.[34]

Pneumothorax precedes or complicates the clinical course of 25 percent of patients with Langerhans'-cell granulomatosis (eosinophilic granulomatosis).[35] Lymphangioleiomyomatosis is a disease characterized by the proliferation of smooth muscle along lymphatic channels that affects women of reproductive age.

TABLE 2. CAUSES OF SECONDARY
SPONTANEOUS PNEUMOTHORAX.*

Airway disease
   Chronic obstructive pulmonary disease
   Cystic fibrosis
   Status asthmaticus
Infectious lung disease
   Pneumocystis carinii pneumonia
   Necrotizing pneumonias (caused by anaerobic,
     gram-negative bacteria or staphylococcus)
Interstitial lung disease
   Sarcoidosis
   Idiopathic pulmonary fibrosis
   Langerhans'-cell granulomatosis
   Lymphangioleiomyomatosis
   Tuberous sclerosis
Connective-tissue disease
   Rheumatoid arthritis (causes pyopneumothorax)
   Ankylosing spondylitis
   Polymyositis and dermatomyositis
   Scleroderma
   Marfan's syndrome
   Ehlers–Danlos syndrome
Cancer
   Sarcoma
   Lung cancer
Thoracic endometriosis (related to menses; causes
   catamenial pneumothorax)

*Categories and disorders are listed according to
frequency of occurrence.

A

B

Figure 1. Chest Radiograph (Panel A) and Computed Tomographic (CT) Scan (Panel B) of a 75-Year-Old Man with a Secondary Spontaneous Pneumothorax Due to Chronic Obstructive Pulmonary Disease.

The patient underwent chest-tube drainage for seven days with persistence of an air leak and the pneumothorax (arrows in Panels A and B). The CT scan shows multiple bullae (arrowheads in Panel B). After transfer to our institution, he underwent video-assisted thoracoscopic surgery, with resection of apical bullae and pleurodesis by insufflation of talc. The air leak resolved and the chest tubes were removed three days after surgery.

Pneumothorax develops in up to 80 percent of patients with lymphangioleiomyomatosis and may be the presenting manifestation of the disease.[36] Pneumothorax in patients with interstitial lung disease presents difficulties in management, because poorly compliant lungs resist reexpansion.

Pneumothorax related to menses typically occurs in women who are 30 to 40 years old and who have a history of pelvic endometriosis.[37] Such a catamenial pneumothorax usually affects the right lung and occurs within 72 hours after the onset of menses. Although uncommon, catamenial pneumothorax is important to recognize, because an accurate history taking can lead to earlier diagnosis, obviating unnecessary diagnostic studies and allowing initial hormonal therapy, followed by pleurodesis if hormonal therapy is not effective. Since the rate of recurrence among women receiving hormonal treatment is 50 percent at one year, pleurodesis should be recommended.[37]

Epidemiology

The incidence of secondary spontaneous pneumothorax is similar to that of primary spontaneous pneumothorax: approximately 6.3 cases per 100,000 population per year among men and 2.0 cases per 100,000 population per year among women.[1] The peak incidence of secondary pneumothorax occurs later in life (age, 60 to 65 years) than does that of primary spontaneous pneumothorax, paralleling the peak incidence of chronic lung disease in the general population.[3]

The incidence of secondary spontaneous pneumothorax in patients with chronic obstructive pulmonary disease is approximately 26 per 100,000 patients with chronic obstructive pulmonary disease per year.[38]

Pathophysiology

When alveolar pressure exceeds the pressure in the interstitium of the lung, as may occur in patients with chronic obstructive pulmonary disease and airway inflammation after coughing, air from the ruptured alveolus moves into the interstitium and backward along the bronchovascular bundle to the hilum of the ipsilateral lung, resulting in pneumomediastinum; if the rupture occurs at the hilum and air moves through the mediastinal parietal pleura into the pleural space, a pneumothorax results.[19] An alternative mechanism for secondary spontaneous pneumothorax may involve air from a ruptured alveolus that moves directly into the pleural space as a result of necrosis of the lung, as occurs with *P. carinii* pneumonia.

Clinical Presentation

In patients with underlying lung disease, dyspnea is always present with pneumothorax and is usually severe, even in those with a small pneumothorax.[38-40] Most patients also have ipsilateral chest pain.[38] Severe hypoxemia or hypotension can occur and be life-threatening.[38,40,41] Symptoms do not resolve spontaneously in patients with secondary spontaneous pneumothorax. Hypercapnia often occurs, with the

partial pressure of arterial carbon dioxide often exceeding 50 mm Hg.[27,38] The physical findings are often subtle and may be masked by the underlying lung disease, particularly in patients with chronic obstructive pulmonary disease. Pneumothorax should always be considered in a patient with chronic obstructive pulmonary disease in whom unexplained dyspnea develops, particularly in association with unilateral chest pain.

Diagnosis

Patients with bullous emphysema may have radiographic evidence of a giant bulla that may appear to be a pneumothorax. A clue to the presence of pneumothorax is a visceral pleural line that runs parallel to the chest wall; bullous lesions that abut the chest wall have a concave appearance. In patients in whom the diagnosis is not clear, computed tomography of the chest should be performed to differentiate between these two conditions, because only pneumothorax should be treated with tube thoracostomy.[42]

Recurrence

The rates of recurrence for secondary spontaneous pneumothorax are similar to those for primary spontaneous pneumothorax, ranging from 39 percent to 47 percent.[25,27,43]

TREATMENT

The management of pneumothorax centers on evacuating air from the pleural space and preventing recurrences. Available therapeutic options include simple observation; simple aspiration with a catheter, with immediate removal of the catheter after pleural air is evacuated; insertion of a chest tube; pleurodesis; thoracoscopy through a single insertion port into the chest; video-assisted thoracoscopic surgery; and thoracotomy. The selection of an approach depends on the size of the pneumothorax, the severity of symptoms, whether there is a persistent air leak, and whether the pneumothorax is primary or secondary.

Reexpansion of the Lung

With a small primary spontaneous pneumothorax (one involving <15 percent of the hemithorax), patients may have minimal symptoms. Supplemental oxygen accelerates by a factor of four the reabsorption of air by the pleura, which occurs at a rate of 2 percent per day in patients breathing room air.[44] Most physicians hospitalize patients with a small pneumothorax, although the treatment of healthy, young patients who are likely to comply with treatment plans may be managed at home after six hours of observation in the emergency department if such patients can obtain emergency services quickly.

Primary spontaneous pneumothoraxes that are large (involving ≥15 percent of the hemithorax) or progressive may be drained by simple aspiration with a plastic intravenous catheter, thoracentesis catheter, or small-bore (7 to 14 French) catheter or by the insertion of a chest tube. Simple aspiration is successful in 70 percent of patients with moderate-sized primary spontaneous pneumothorax.[45] If the patient is more than 50 years old, or if more than 2.5 liters of air is aspirated, this method is likely to fail.[45] Successfully treated patients can be discharged from emergency departments with follow-up within several days if a chest radiograph obtained six hours after aspiration shows resolution of the pneumothorax and if such patients can obtain emergency services quickly. If aspiration through a catheter fails to expand the lung, the catheter can be attached to a one-way Heimlich valve or a water-seal device and used as a chest tube.

Primary spontaneous pneumothorax may also be managed with a chest tube that is left in place for one or more days. Because air leakage is usually minimal, a small-bore (7 to 14 French) chest catheter usually suffices.[46-49] The catheter can be attached to a one-way Heimlich valve, which allows ambulation,[48,50] or to a water-seal device.[47,48] Routine application of suction (with a pressure of 20 cm of water) has not been shown to improve the outcome.[51] We reserve the use of water-seal devices and suction for patients in whom Heimlich valves fail or those who have coexisting nonrespiratory conditions that reduce the ability to tolerate a recurrent pneumothorax. Drainage through a chest tube has a success rate of 90 percent for treatment of a first pneumothorax, but the rate decreases to 52 percent for treatment of a first recurrence and to 15 percent for treatment of a second recurrence.[52] Large air leaks and pleural effusions that clog the catheter contribute to failure.[48]

Secondary spontaneous pneumothorax should be managed with a chest tube (20 to 28 French) attached to a water-seal device, and patients should be hospitalized, because of the risk of respiratory compromise. Suction can be reserved for patients with ongoing air leaks and those in whom the lung fails to reexpand after drainage through a water-seal device.

Complications of chest-tube drainage include pain, pleural infection, incorrect placement of the tube, hemorrhage, and hypotension[53] and pulmonary edema[54] due to lung reexpansion.

Persistent Air Leaks

Persistent air leaks are more common with secondary pneumothorax than with primary pneumothorax. Seventy-five percent of air leaks in primary spontaneous pneumothorax and 61 percent of air leaks in secondary spontaneous pneumothorax resolve after 7 days of chest drainage, but 100 percent and 79 percent, respectively, resolve after 15 days. Another study reported a lower likelihood of eventual resolution of air leaks that persist for longer than two days.[55]

We reassure patients with a first primary spontaneous pneumothorax, at the time the chest tube is in-

serted, that surgery is usually unnecessary. However, surgery does become a consideration if an air leak persists for four to seven days. On the seventh day of an air leak, we discuss the available surgical alternatives with the patient. Patients must consider the relative benefits and risks of a prolonged hospitalization, the possibility of a recurrence of pneumothorax at a later date without surgery, and the benefit of surgery in accelerating recovery and preventing recurrences. Most of our patients request surgical intervention after seven days of a persistent air leak.

For an initial secondary spontaneous pneumothorax, we recommend surgery for patients who are suitable candidates. It is important to prevent recurrences, regardless of the presence or absence of an air leak, because of the seriousness of this condition. Some centers, however, maintain drainage through a chest tube for two weeks before undertaking a surgical intervention.[56]

Some experts recommend selecting patients with primary or secondary pneumothorax and persistent air leaks for immediate surgery according to whether or not bullae have been detected by chest computed tomographic scanning.[57] There is no evidence, however, that the appearance of the lung on computed tomography corresponds to the likelihood that an air leak will not resolve spontaneously.[58] Chemical pleurodesis with the intrapleural instillation of a sclerosing agent has a low rate of success among patients with persistent air leaks.[59]

Preventing Recurrences

In the absence of a persistent air leak, decisions about the prevention of recurrences in patients with primary spontaneous pneumothorax must be individualized. We recommend interventions to prevent recurrence after the second ipsilateral pneumothorax. Some centers, however, recommend such measures for all patients with a first primary spontaneous pneumothorax.[29,60] Patients who plan to continue activities that increase the risk that complications will result from a pneumothorax (e.g., flying or diving) should undergo preventive treatment after the first episode. We still caution against such activities, however, because of the risk of a contralateral pneumothorax.

Recent data suggest that age is an independent predictor of the risk of recurrence of primary spontaneous pneumothorax.[25] Since most recurrences occur within three years of the first pneumothorax and risk decreases after the age of 40 years, younger patients are at risk for a longer period and have a greater likelihood of benefiting from preventive procedures after a first pneumothorax than older patients.

Interventions to Prevent Recurrences

The instillation of sclerosing agents through chest tubes in the absence of air leaks is associated with a recurrence rate of 8 to 25 percent,[27,29] which is higher than the rate associated with other available methods. Thoracoscopy through a single chest port performed under direct visualization allows the resection of small apical bullae (those approximately <2 cm in diameter) and pleurodesis by mechanical pleural abrasion or insufflation of talc.[61,62] Two grams of talc is used, in contrast with the 5 g recommended for pleurodesis of malignant pleural effusions.[63] The treatment of patients found at thoracoscopy to have bullae ≥2 cm in diameter can be switched to video-assisted thoracoscopic surgery or thoracotomy. The success rate for thoracoscopy with insufflation of talc is approximately 97 percent, with a recurrence rate of 5 to 9 percent.[61] There is concern about the use of talc, however, because of reports of acute lung injury and respiratory failure.[64]

Video-assisted thoracoscopic surgery with multiple chest ports allows wide visualization of the pleural space for the resection of bullae and pleurodesis (Table 3).[65-71] The rate of complications associated with video-assisted thoracoscopic surgery is higher among patients with secondary pneumothorax than among those with primary pneumothorax.[65,70] A limited axillary approach that spares the thoracic muscles is used in thoracotomy for the management of pneumothorax (limited thoracotomy).[72] Some patients with extensive bullae may still require the wider exposure provided by full thoracotomy.[73]

There are limited data comparing the relative benefits of various interventions to prevent pneumothorax. Recurrence rates with video-assisted thoracoscopic surgery vary from 2 to 14 percent,[64-71] as compared with a range of 0 to 7 percent (as most often reported less than 1 percent) for limited thoracotomy.[74-76] The higher rates of recurrence after video-assisted thoracoscopic surgery may result from less adequate exposure of the chest cavity than with thoracotomy for detection and resection of apical bullae.[75]

Some studies,[77,78] but not all,[70,79] indicate that the duration of hospitalization, the need for postoperative drainage through a chest tube, and the severity of perioperative and postoperative pain are less with video-assisted thoracoscopic surgery than with limited thoracotomy, although formal analyses of cost effectiveness have not been performed.[80] Between 2 and 10 percent of patients with primary spontaneous pneumothorax and up to 29 percent of patients with secondary spontaneous pneumothorax who undergo video-assisted thoracoscopic surgery require a change to thoracotomy because of technical difficulties.[68,80]

Patients with severe underlying lung disease may not be able to tolerate video-assisted thoracoscopic surgery, because most surgeons collapse the ipsilateral lung during the procedure. A recent report indicates, however, that patients with respiratory compromise can undergo video-assisted thoracoscopic surgery under local and epidural anesthesia without complete deflation of the lung.[81]

TABLE 3. TECHNIQUES USED DURING
VIDEO-ASSISTED THORACOSCOPIC SURGERY.

Pleural symphysis

Insufflation of talc
Mechanical pleural abrasion
Ablation with a neodymium:yttrium–aluminum–
    garnet laser
Partial pleurectomy

Removal of bullae

Stapler resection
Loop ligation
Electrocoagulation
Ablation with a neodymium:yttrium–aluminum–
    garnet laser
Ablation with a carbon dioxide laser
Ablation with an argon laser
Wedge resection
Oversewing

The intervention used for the prevention of recurrence should depend on the available technical expertise. We prefer an approach that uses thoracoscopy through a single chest port, with patients found to have large apical bullae switched to video-assisted thoracoscopic surgery or a limited thoracotomy.

Patients with HIV Infection

Patients with the acquired immunodeficiency syndrome (AIDS) in whom pneumothorax develops have a poor prognosis because of the late stage of their HIV infection.[82] Most patients die of AIDS-related complications within three to six months after pneumothorax develops. The therapeutic approach to pneumothorax therefore depends on the underlying prognosis. Because of the high rate of recurrence associated with chest-tube drainage alone, the instillation of a sclerosing agent through a chest tube is indicated even in the absence of an air leak.[83] Surgical resection of parenchymal sources of air leaks benefits patients with early HIV disease. Frequently, there is necrotic lung tissue that requires resection. After stabilization, patients with a poor underlying prognosis may do best with outpatient care with a small-bore chest catheter and Heimlich valve.[84]

Future Directions

Refinements of minimally invasive procedures, such as video-assisted thoracoscopic surgery, promise further improvements in the care of patients with spontaneous pneumothorax. A better understanding of the risk factors for the recurrence of primary pneumothorax will assist physicians in the selection of patients for preventive treatment. Improved understanding of the mechanisms of action of sclerosing agents[85] should lead to the development of more effective agents and improve the effectiveness of chemical pleurodesis.

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