Pressure-dependent persistent air leak in a patient with secondary spontaneous pneumothorax

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ABSTRACT

An air leak lasting more than 5–7 days (persistent air leak, PAL) can complicate up to 40% of patients with secondary spontaneous pneumothorax. Chronic obstructive pulmonary disease is the most common cause of secondary spontaneous pneumothorax, and early surgical intervention has been recommended for patients with PAL. Bullectomy or blebectomy with concomitant mechanical pleurodesis by medical thoracoscopy or video assisted thoracoscopic surgery is considered definitive therapy. Unfortunately, the perioperative course following lung resection can also be complicated by air leaks leading to worse clinical outcomes. Post lung resection air leak can be pressure independent or pressure dependent (also known as drainage-related air leak). The distinction between these two entities is crucial as the management varies drastically. Pleural manometry may play an important role in the early diagnosis of pressure-dependent PAL preventing further unnecessary surgical procedures from being performed.

Key Indexing Terms: Pneumothorax; Persistent air leak; Lung resection; Pressure; Dependent.. **[Am J Med Sci 2022;364 (6):782–788.]**

INTRODUCTION

Secondary spontaneous pneumothorax refers to the occurrence of pneumothorax in patients with preexisting lung disease. The pneumothorax occurs due to the creation of a bronchopleural (BPF) or alveolopleural fistula (APF), causing progressive accumulation of air in the pleural space with a subsequent increase in the pleural pressure resulting in lung collapse. Although most BPF or APF resolves with drainage of the pleural space and supportive care, approximately 40% of patients suffer from persistent air leak (PAL) due to ongoing communication between the pulmonary parenchyma and the pleural space.[1] Although somewhat arbitrary, an air leak (AL) lasting more than 5–7 days is generally accepted as the duration cut off for a diagnosis of PAL.[2] Different modalities are available for the treatment of PAL in patients with SSP. Surgical bullectomy or blebectomy with or without resection of adjacent pulmonary parenchyma and some kind of pleural intervention represents the definitive therapy.[3]

Unfortunately, post-surgical complications, including post lung resection PAL, can also complicate the clinical course of these patients. Different surgical techniques have been employed to minimize the risk of air leak. However, PAL still occurs in a significant number of patients.[4] Post lung resection air leak can be either pressure dependent or pressure independent. Pressure-dependent air leak has also been described as drainage related air leak. This manuscript describes a 39-year-old young female who suffered from secondary spontaneous pneumothorax and PAL, requiring definitive surgical treatment only to be complicated by post lung resection air leak. The air leak was eventually identified as pressure-dependent air leak using pleural manometry. The chest tube was safely removed, and the patient made a complete recovery without any additional surgical intervention.

CASE PRESENTATION

A 39-year old female presented to the emergency department (ED) with worsening right sided chest pain and shortness of breath. The pain started following an episode of vigorous coughing induced by an aspiration

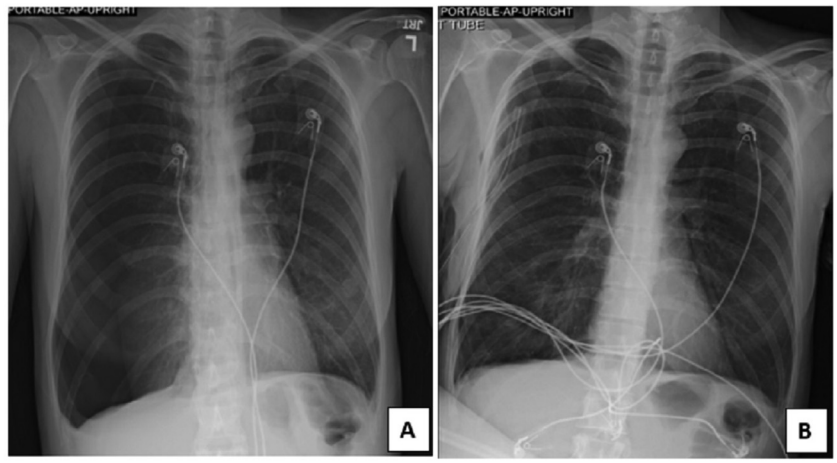

FIG. 1. Antero-posterior chest X-ray showing hyperinflated right hemithorax with a large right sided pneumothorax without any mediastinal shift (A). Post tube thoracostomy chest radiography revealed improved pneumothorax. The chest tube was in good position (B).

event approximately 2 h ago. She had no known medical problems and did not take any routine medications. She smoked two packs per day and had been smoking since she was eleven years old. Additionally, she also admitted to smoking marijuana regularly for more than 10 years.

In the ED, her vital signs showed a blood pressure of 107/87 mmHg, a heart rate of 110 beats per minute, a temperature of 98 F, a respiratory rate of 27 breaths per minute, and oxygen saturation of 92% on room air. The patient was in visible distress from pain. Chest examination revealed a hyperinflated right hemithorax with reduced excursion on palpation compared to the left, hypertympanic to percussion, with absent breath sound and vocal resonance on auscultation.

Laboratory workup demonstrated mild leukocytosis. A chest radiograph showed a large right-sided pneumothorax without evidence of tension (Fig. 1A). The patient underwent tube thoracostomy with radiologic improvement of the pneumothorax (Fig. 1B). There was a grade 4 air leak as per Cerfolio classification. The patient was managed conservatively for the next six days without any significant improvement of the air leak. A computed tomographic (CT) scan of the chest showed a small apical pneumothorax (Fig. 2A). Extensive bilateral upper lobe centrilobular emphysema with bullous disease was noted (Fig. 2B). Due to PAL, she underwent a thoracoscopic bullectomy with mechanical pleurodesis. Despite the intervention, the air leak persisted. The patient then underwent thoracotomy with partial resection of the right upper lobe and a repeat mechanical pleurodesis. Postoperatively, chest radiography showed persistent apical pneumothorax (Fig. 3).

The air leak resolved during tidal breathing but persisted with cough and application of suction to the chest tube. In the next 48 h, the chest tube was connected to water seal drainage without any application of suction. The pneumothorax persisted. Clamping the chest tube also did not worsen the pneumothorax. A pleural manometry was performed, first with the chest tube open to water seal and then with the tube clamped (Fig. 4). The manometry tracings were consistent with pressure-dependent air leak. The diagnosis of pressure-

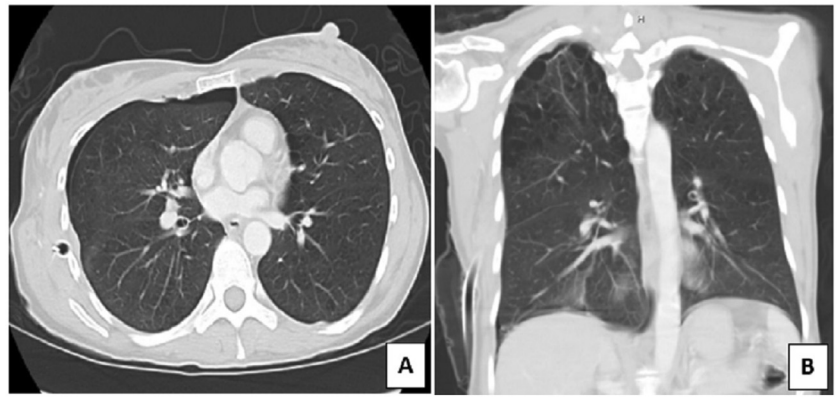

FIG. 2. Axial computed tomography (CT) of the chest revealed a small apical pneumothorax (A). Coronal view (B) revealed bilateral apical bullous disease.

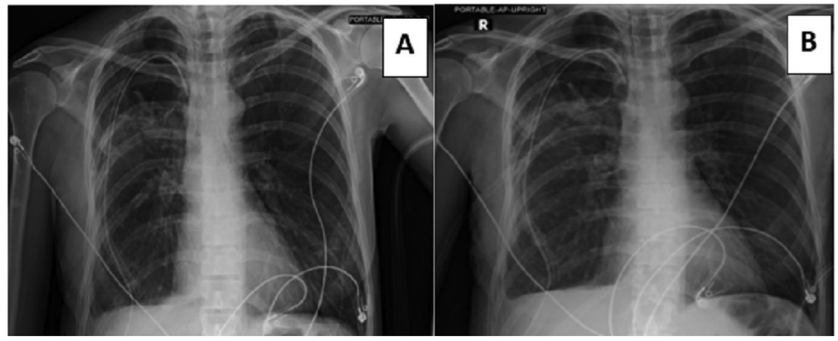

FIG. 3. Chest X-ray obtained 24 (A) and 48-hours (B) without suction showed persistent small apical pneumothorax.

dependent PAL due to the application of negative suction after partial lung resection was made. The chest tube was removed. Follow-up chest radiography after 24 h revealed stable pneumothorax that remained stable after two weeks (Fig. 5).

DISCUSSION

We have presented a case of secondary spontaneous pneumothorax complicated by PAL requiring multiple surgical interventions consisting of thoracoscopic bullectomy followed by thoracotomy and partial resection of the RUL. The perioperative period was complicated by persistent Grade 1 air leak that was eventually diagnosed as pressure-dependent air leak by pleural manometry.

Although any lung disease can be associated with secondary spontaneous pneumothorax, chronic obstructive pulmonary disease (COPD) is the most common culprit accounting for approximately 50–70% of all patients.[5–7] Patients are initially managed with drainage of the pleural cavity by chest drainage, with data showing similar outcomes between smaller bore pigtail catheters (10–14Fr) versus large bore chest tubes (>22Fr), and

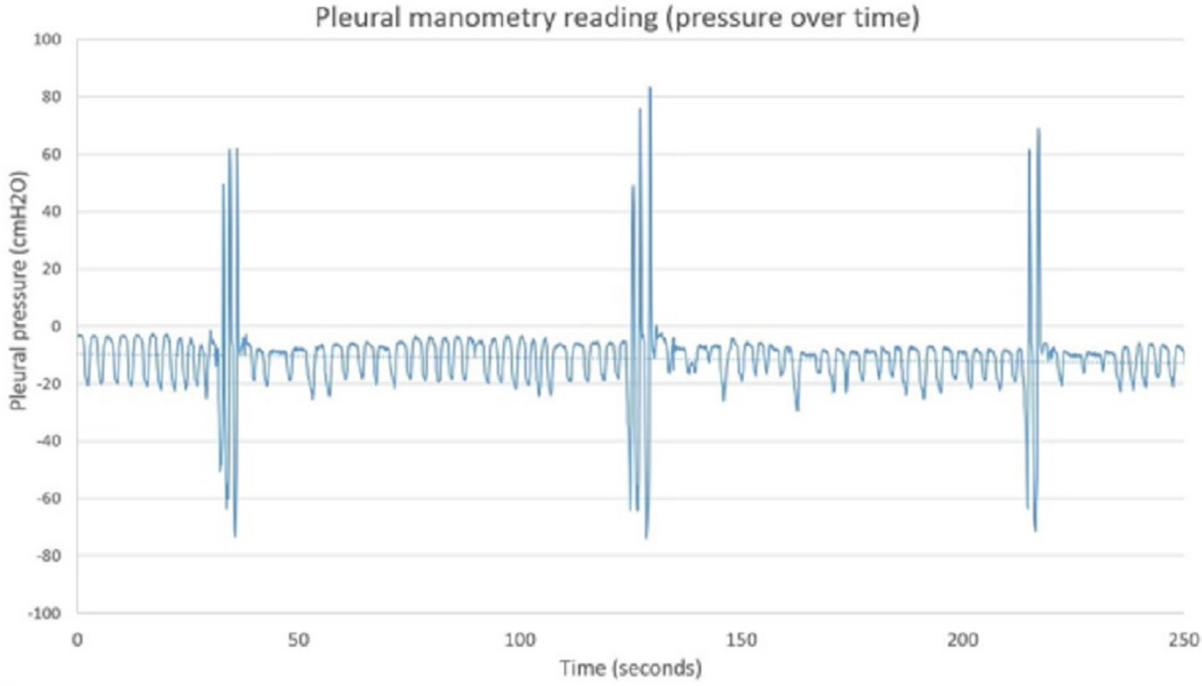

FIG. 4. Pleural manometry tracings with clamped chest tube. Subatmospheric pleural pressure was seen at baseline. The baseline is representative of tidal breathing. The spikes are due to forced expiratory maneuver (cough). During the cough manuever, the pleural pressure initially decresed due to sharp inspiration followed by an increase with subsequent return to the baseline. The baseline pleural pressure remained unchanged in between and following the three cough maneuvers suggesting no air leak during the cough manuevers. These manometry findings are consistent with pressure dependent air leak where the air leak occurs only in response to a redution in the pleural pressure . In contrast, the pleural manometry in patients with pressure-independent air leak will demonstrate a progressive increase in basline end-expiratory pressure following the cough maneuvers due to ongoing air leak from alveolar pleural fistula.

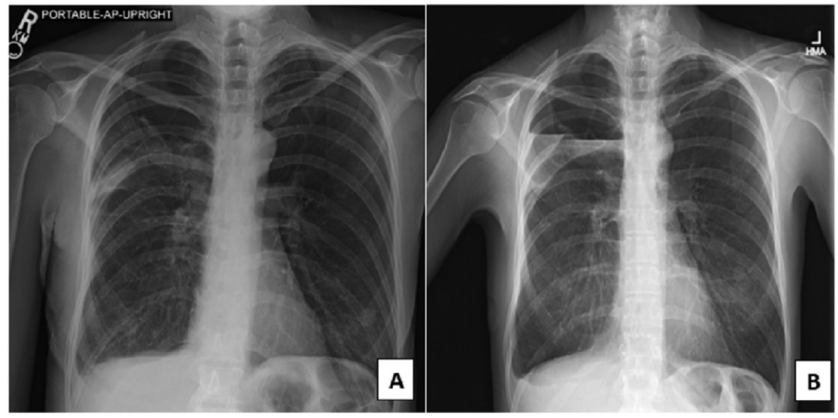

FIG. 5. Chest X-ray after chest tube removal revealed stable small apical pneumothorax (A). Chest X-ray after 2 weeks revealed stable pneumothorax with obliteration of right costo-phrenic angle and loculated apical effusion likely due to the previous pleurodesis.

better tolerability with smaller bore tubes.[8] Continued observation and appropriate assessment of air leak are necessary to guide further treatment. The Cerfolio classification is commonly used to assess the degree of air leak.[9] According to this classification, the air leak is graded from 1 to 4, based on the phase of the respiratory cycle when the air leak is observed. Patients with grade 1 air leak only demonstrate air leak during forced expiratory maneuvers, such as coughing. Grade 2 and 3 refers to air leak with passive expiration and inspiration, respectively. Grade 4 air leak is present during inspiration, expiration, and forced expiratory maneuvers.[9] Grade 4 signifies the worst air leak, whereas grade 1 represents the least air leak. Digital chest drainage systems have also been used to assess the exact quantification and severity of the air leak, although may not be available in all centers.[10] For Patients in whom there is a rapid resolution of the air leak following tube thoracostomy, the chest tube can be removed early, and they should be considered for definitive treatment of their underlying lung disease whenever possible. Some clinicians recommend performing pleurodesis as definitive therapy after the first episode of a secondary spontaneous pneumothorax. The management, however, can be challenging for patients who have air leak lasting greater than 2 days.[11] Although recent consensus guidelines have recommended early surgical intervention for patients with PAL lasting 4 days or more, one study showed that 80% of patients had resolution of the air leak when managed conservatively for 14 days.[1,12,13]

Patients with PAL have traditionally been managed surgically with bullectomy or blebectomy with concomitant mechanical pleurodesis by medical thoracoscopy or video assisted thoracoscopic surgery (VATS).[14] If the VATS fails, open thoracotomy has been recommended. A relatively newer technique in the management of PAL is the use of endobronchial valves (EBVs). Although not approved by the Food and Drug Administration (FDA) for this particular indication, there are numerous reports of successful use of EBVs in patients with PAL in the literature.[15,16] The EBVs prevent airflow into the distal airways but allows exhalation and drainage of the airway secretion into the proximal airways. Due to the inherent mechanism of action, EBVs are an excellent option for the management of PAL. However, the success of the procedure depends on the isolation of the correct airway and the absence of any significant collateral ventilation.[17]

Air leak after lung resection is common. The incidence of air leak varies based on the type of the surgery and the timing of assessment. For example, the risk of air leak is higher with lobectomy compared to segmentectomy or wedge resection.[18] Similarly, the incidence of air leak is much greater in the earlier post operative phase than later. The incidence of air leak varies between 24 and 48% when assessed on the first post-operative day.[9,18,19] Although most air leaks do seal up, there are incidences of post-operatively air leak lasting more than 5 days.[20] PALs occur in 6–26% post lung resection patients and are associated with increased morbidity, length of hospital stay and healthcare cost.[10,21–24] Moreover, it may lead to additional surgical interventions.

The air leak can occur due to surgical complications, such as anastomotic failure or leakage of air along the suture lines; therefore, checking for intraoperative air leak is crucial. A number of risk factors are associated with a higher risk of air leak and include female gender, advanced age, presence of emphysema, chronic obstructive pulmonary disease (COPD), low forced expiratory volume in first second (FEV_1) and diffusion capacity for carbon monoxide (D_LCO), and chronic steroid use.[25,26] Different surgical techniques, including the use of sealants have been devised to reduce intraoperative air leak and, eventually PAL.[2,27] Importantly, surgical complications are not the only etiology for air leak in post-surgical patients. In some cases, it can also be due to pressure-dependent air leak resulting from the application of negative intrapleural suction via the drainage system. This distinction is clinically important as in the latter type of air leak – chest tube(s) can be removed without adverse clinical consequences.

Post lung resection pressure-dependent air leak is a relatively underappreciated entity. This condition has also been referred to as drainage-dependent air leak, as the air leak is only present when suction is applied to a pleural drain or during forced expiratory maneuver (cough) with an unclamped chest tube. However, if the circuit is closed by clamping the chest tube, the air leak (from the lung into the pleural space) disappears. The air leak is caused by a relative mismatch between the size of the resected lung and thoracic cage, and the air leak occurs only in response to a reduction of pleural pressure. In contrast, pressure-independent air leak is associated with air leak irrespective of pleural space evacuation by suctioning. If drainage is discontinued, patients with pressure-independent air leak may develop worsening pneumothorax and lung collapse. Some authors have described pressure-independent air leak as drainage-independent air leak as the air leak into the pleural space is not dependent on the negative suction.[28] Pressure-dependent air leak was initially described after pleural fluid drainage in patients with nonexpandable lung (NEL). Post lung resection patients can have both pressure-dependent and independent air leak, and this distinction is crucial. Pleural manometry can distinguish between these two entities as clinical evaluation may be inadequate.[29–31]

The pressure-dependent air leak results from a lung to thoracic cage size mismatch. This mismatch in shape and volume causes distortion and distension of the alveolus adjacent to the resected lung and temporarily opens APF. These APFs eventually cease as equalization of the pressure within the thoracic cavity is achieved, resolving the alveolar distortion. Application of drainage creates a constant opening allowing for the evacuation of air and promotes a negative pressure gradient within the pleural space resulting in ongoing air leak.[29,32,33] An important clue that raises the suspicion of pressure-dependent air leak is that the pneumothorax persists despite the application of suction, as there is a shape mismatch leading to the development of an irreducible space. Pressure-independent air leak results from a true parenchymal injury and will occur independent of the pleural pressure, eventually culminating in a tension pneumothorax.

There are no recommended guidelines for the management of PAL following lung resection. The management often depends on institutional policies or individual practice patterns. Generally, negative suction is applied through the chest tube for a certain duration of time (often arbitrary), especially in the immediate post-operative period, followed by a trial of chest tube connected to the water seal without any suction. If there is a new development or worsening of the pneumothorax or subcutaneous emphysema, the suction is reapplied. If there is PAL without any clinical or radiological deterioration that can be managed with water seal drainage only, patients can be considered for one way valve connected to the chest tube for discharge from the hospital. However, this approach is not standardized, and the comfort level to discharge a patient may vary widely among clinicians. Pleural manometry offers real-time measurement of the pleural pressure and can safely differentiate between pressure-independent and dependent air leaks assisting with confident decision making.[28,29,33] When pleural manometry is performed during tidal breathing with a clamped chest tube, patients with pressure-independent air leak demonstrate a progressive increase in their baseline pleural pressure due to ongoing air leak into the pleural space. But in pressure-dependent air leak, the pleural pressure remains constant. Therefore, removal of the chest drainage will not result in worsening pneumothorax and is safe.[30] Similarly, patients with pressure-independent PAL may require additional intervention for correction of the air leak, but patients with pressure-dependent air leak would not.

This phenomenon of pressure-dependent air leak has also been described in patients with pneumothorax *ex vacuo*. When pleural fluid is drained in the setting of a non-expandable lung (NEL), the restricted visceral pleura is unable to approximate with the parietal pleura and chest wall creating a “vacuum.” This negative pressure results in localized alveolar stretch and deformation, causing air to escape. Once the negative pressure is relieved by the replacement of air, the alveolus returns to its original conformation and abolishes the air leak.

The definition of PAL is arbitrary and changing. In the past, air leak lasting more than 5–7 days was defined as PAL.[34] Due to innovative (use of sealants) and minimally invasive surgical techniques (VATS vs. thoracotomy), more rapid recovery and discharge of patients after lung resection is the current norm. In a study analyzing the data from more than 11,00 patients who underwent uncomplicated lobectomy, the median length of hospital stay (LOS) was 5 days.[35] Patients who underwent minimally invasive procedures rather than thoracotomy had a median LOS of 4 days. Interestingly, more than 20% of patients were discharged within 3 days. Due to the immense emphasis on reducing LOS and healthcare cost savings, some authors have proposed that rather than a definite timeline, PAL should be defined as an air leak that prevents hospital discharge following lung resection. An early distinction between pressure-independent and pressure-dependent air leak could be an important tool to improve patient-centered outcomes.

CONCLUSIONS

Despite advanced surgical techniques, post lung resection air leak continues to be a common problem. Appropriate characterization of the air leak is essential for proper care for the patient and avoidance of unnecessary surgical interventions. Pressure-dependent or drainage-related air leak can be confidently distinguished from pressure-independent air leak by pleural manometry. Persistence of pneumothorax despite suction could be the earliest clue for the presence of a pressure dependent process, and pleural manometry should be considered in such situations.

AUTHOR CONTRIBUTIONS

All authors were involved in the planning, collection of data, preparation of the initial and final manuscript.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Biplab K. Saha: Conceptualization, Data collection and analysis, Preparation of the inittial and final manuscript. **Woon Hean Chong:** Data collection and analysis, Preparation of the initial and final manuscript. **Kurt Hu:** Data collection, Preparation of initial and final manuscript. **Santu Saha:** Conceptualization, Data analysis, Preparation of the initial and final manuscript. **Alyssa Bonnier:** Conceptualization, Collection of data, Preparation of initial and final manuscript. **Praveen Chenna:** Supervision for the preparation of the final manuscript.

CONFLICTS OF INTEREST

The author has no financial or other conflicts of interest to disclose.

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