

Understanding Spontaneous Pneumothorax: A Review of Key Facts and Trends

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Abstract

Pneumothorax, characterized by the entry of air into the pleural space, has a rich history dating back to ancient Greece. The comprehensive review aims to enhance the understanding of spontaneous pneumothorax (SP), offering valuable insights into its classification, pathophysiology, epidemiology, chief complaints, clinical signs, complications, risk factors, diagnostic tools, and management strategies. The International Classification of Diseases Eleventh Revision (ICD-11) includes primary spontaneous pneumothorax (PSP) and secondary spontaneous pneumothorax (SSP) into the other spontaneous pneumothorax category. SP incidence rates vary globally, with predisposition in younger males and older females. Chief complaints typically include dyspnea and pleuritic chest pain, while additional clinical signs involve altered SpO₂ levels, increased heart and respiratory rates, and reduced chest wall expansion in severe cases. Diagnostic tools, ranging from chest X-rays to computed tomography scans and ultrasound, play crucial roles in accurate diagnosis, considering variations in disease presentation. Conservative and non-surgical management approaches are favoured, with observation, simple aspiration, and chest physiotherapy demonstrating efficacy. Surgical interventions, such as video-assisted thoracic surgery (VATS) and open thoracotomy, become considerations in recurrent or severe cases. This article reviews key facts and trends, providing a comprehensive overview of the multifaceted nature of spontaneous pneumothorax and the importance of tailored approaches to SP based on individual patient characteristics and symptoms.

Keywords: Pneumothorax; Risk factors; Tuberculosis; Epidemiology

1. Definition and History

Pneumothorax is when air leaks into the pleural space, which normally only holds a predetermined quantity of serous fluid that is tightly regulated to avoid lung depletion. Pneumothorax had been known since the Hippocrates era when ancient Greek doctors would identify hydropneumothorax by searching for a “succussion splash” in the patient's chest (Huan, Sidhu and Thomas, 2021). In 1803, a French physician, Jean Marc Gaspard Itard, was the first to describe the condition. Then, his mentor, René Laennec characterized its clinical and anatomical details in 1819 (Papagiannis et al., 2015). Before 1932, pneumothorax cases were commonly thought to be secondary to pulmonary tuberculosis. This is because Kjaergaard published the first modern description of the condition within the year. He also clarified the distinction between primary and secondary pneumothorax in his publication (Huan, Sidhu and Thomas, 2021).

2. Classification by Etiology

The International Classification of Diseases Eleventh Revision (ICD-11) classified pneumothorax into spontaneous tension pneumothorax and other spontaneous pneumothorax. PSP and SSP are included in the latter category.

This classification is based on whether or not tension is present. According to the ICD-11, PSP commonly happens in tall and thin young men without prior lung disease diagnosis and healthy lung appearance in CXR. Spontaneous rupture of subpleural apical blebs or bullous is thought to be the cause of PSP that manifested from either inheritance or years of smoking. As for SSP, it takes place in patients with underlying pulmonary disease that may progress into pleural bleb or bulla rupture (World Health Organisation, 2019). Lung diseases such as COPD, tuberculosis, pulmonary emphysema, and acute severe asthma may elevate the risk of acquiring SSP (Zarogoulidis et al., 2014).

3. Pathophysiology

In a normal condition, the intrapleural pressure is negative compared to the pressure of the atmosphere. The pressure contrast causes automatic lung recoil and it is the negative pressure that prevents the lungs from collapsing. The most fundamental aspect of the pathophysiology behind pneumothorax is the entry of air into the pleural space which disrupts the existing surface tension and negative pressure that holds the pleural layers together. The presence of air in the pleural space erases the pressure difference, thus resulting in a pathological pressure equilibrium (Choi, 2014). Air leakage can be caused by multiple reasons such as increased alveolar pressure, weakening of pleura caused by subpleural blebs or bulla, lung necrosis, and other lung tissue abnormalities. In spontaneous pneumothorax, the rupture of pleural blebs or bulla is what allows air to leak into the pleural space, interfering with the pressure gradient and inhibiting lung inflation (Costumbrado and Ghassemzadeh, 2020; McKnight and Burns, 2022). In addition, Tschopp et al., (2015) added that other than the presence of changes on the pleura, known as emphysema-like changes (ELCs), diffused lung porosity may also predispose patients to suffer SP.

4. Epidemiology

A study in England revealed that there were 170,929 individuals hospitalized for spontaneous pneumothorax between 1968 and 2016, with 60.8% of these hospitalizations being associated with SSP. In 2016, 6,372 individuals were diagnosed with spontaneous pneumothorax, and patients with underlying lung disease predominated. Furthermore, it is stated that COPD and asthma were the primary causes of SSP in all age groups of patients. Pulmonary TB was responsible for just 1.0% and 1.4% of spontaneous pneumothorax cases in men and women, respectively (Hallifax et al., 2018). Research in France showed SP statistics indicated that 15% of 42,595 pneumothorax hospital admissions between 2008 – 2011 were due to SSP and the average length of stay (LOS) for SP was 7 days (Bobbio et al., 2015). The age distribution in the two studies from England and France was fairly similar. According to both studies, spontaneous pneumothorax is more likely in younger males and older women. The prior demography is consistent with the findings of a research conducted in Germany by Schnell et al. (2017), who discovered that the highest prevalence of pneumothorax occurs among men aged 20 – 25.

In a peripheral hospital in India, 84 patients experienced secondary spontaneous pneumothorax between April 2014 – March 2015. The study showed that SSP due to pulmonary tuberculosis was the most common condition, accounting for 42 (50%) patients (Gayatridevi et al., 2015). This showed similarity with a paper from Indonesia that

reported out of 104 pneumothorax patients, 37 (35.5%) of them had TB (Widjaya et al., 2014). Additionally, both articles reported hospital stay duration, ranging from 5 to 90 days in India and about 31.1 days in Indonesia, depending on the underlying lung condition, with SP secondary to TB having the longest hospitalization. On top of that, the mean age for SP patients in India is 41.8 years, ranging from 15 to 80 years. Likewise, the age distribution in Indonesia ranged from 17 – 81 years, with a mean of 39.7 years (Gayatri Devi et al., 2015; Widjaya et al., 2014). On the other hand, the most common cause of SSP in Japan differs from that of India and Indonesia. Japan indicates that pulmonary emphysema is the top cause of SSP in the country, accounting for 195 people between 2004 and 2010. Another distinction can be seen in the incidence. Within the total of 751 SP cases studied in Japan, PSP patients appear to outnumber SSP patients. According to the study, the average age of PSP patients is 27 years old, whereas PSS patients are 70 years old. Furthermore, the national average LOS for SP was just 11 days (Onuki et al., 2017).

5. Chief Complaints

The primary symptoms of pneumothorax are identical regardless of its different etiologies. According to studies conducted in India, Japan, and Turkey, the most typical clinical signs of a spontaneous pneumothorax include dyspnea and pleuritic chest pain (Gayatri Devi et al., 2015; Ince et al., 2013; Onuki et al., 2017). A study by Huan et al. (2021) in Malaysia mentioned that dyspnea is more commonly found in SSP patients, while PSP patients usually present with chest pain. On that note, patients may also complain of feeling uncomfortable while inhaling, but the sensation is frequently limited to the SP site (Choi, 2014). Following the aforementioned symptoms, coughing also appears to be a dominant manifestation of pneumothorax in India and Indonesia (Gayatri Devi et al., 2015; Widjaya et al., 2014). Specifically for PSP, symptoms may be minimal or not appear at all. If severe manifestation occurs, a complication may be present (Tschopp et al., 2015).

Along with the chief complaint of pneumothorax, there are additional manifestations that may suggest the condition. Research conducted in Australia revealed a drop in SpO₂ levels as well as an elevated heart rate and respiratory rate that correlates with the size of pneumothorax in individuals with PSP. However, it was noted that these irregular parameters do not correspond with the size of the pneumothorax in SSP patients, even though they are more likely to occur in SSP patients (Brown et al., 2014). In addition, individuals with pneumothorax involving more than 15% of the hemithorax may have a reduction in chest wall expansion, hyper resonance during percussion, and diminished or missing tactile fremitus as well as breath sounds (Costumbrado and Ghassemzadeh, 2020).

6. Complications

Despite the potential for spontaneous recovery, SP severity may worsen due to certain factors. Fatal complications in PSP are rare, in accordance to the uncomplicated characteristics of the condition. On the other hand, SSP may result in a more severe progression. A study by Widjaya et al. (2014) mentioned that the leading cause of death in SP patients are respiratory failure, followed by sepsis and septic shock. In addition, Brown et al. (2014) indicated that treatment mistakes may also lead to complications in SP patients. Improper chest drainage can result in organ damage,

hemorrhage, infection, and death. These problems were discovered in 11% of the patients investigated, with a higher prevalence in SSP instances. In addition, prolonged persistent spontaneous pneumothorax pushes the formation of bronchopleural fistulas. When this condition is poorly treated, patients may end up with life-threatening tension pneumothorax. Emergency surgical repair of the fistulas must be immediately performed in these situations (Salik, Vashisht and Abramowicz, 2020). Furthermore, patients should also be informed about the possibility of SP recurrence. The likelihood of recurrence is quite high in the first three to five years after the initial SP diagnosis, according to McKnight and Burns (2022).

7. Risk Factor

The occurrence of SP is more prevalent in particular age groups and sexes. Although certain ages and sexes may not necessarily predict the development of SP, both are significant factors in the occurrence of pneumothorax if accompanied by other health risks. A 2019 research from France indicated that 78.2% of spontaneous pneumothorax patients in the study were males; this finding is consistent with studies from England and Germany, which both reported a greater frequency of SP in men than in women (Hallifax et al., 2018; Kepka et al., 2019; Schnell et al., 2017). Regarding the age risk factor, several published research has found that SP occurs in similar age groups in men and women. Schnell et al. (2017) discovered that SP in men peaked around the ages of 20 - 25 years and 70 - 75 years, but SP in women only peaked slightly at the age of 25 - 30 years (Figure 2.3). Furthermore, Hallifax et al. (2018) provided SP age ranges that were closely similar, and they went on to show the exact age range for primary and secondary spontaneous pneumothorax. For PSP, the male population peaked at the age of 20 years and the female population peaked at the age of 25 years, followed by a second, smaller peak in both sexes at the age of ≥ 85 years. In terms of SSP, 80-year-old males and 70-year-old females had the biggest spikes.

8. Diagnostic Tools

The guidelines for the treatment of pneumothorax from the United Kingdom and Germany advise that the Posterior-Anterior (PA) chest X-ray be utilized as the primary imaging modality to diagnose the condition. It is claimed that the upright and inspiration position is the most efficient for determining pneumothorax because it permits sufficient evaluation of the lung parenchyma to rule out other pulmonary abnormalities (MacDuff, Arnold and Harvey, 2010; Schnell et al., 2018). Chest X-ray is most helpful in identifying PSP, but further imaging may be required for SSP since chest X-ray may not be able to detect interstitial lung disease and lung bullous, if both of the abnormalities are present it may be overlooked in X-rays and complicate the diagnosing process (Ruppert et al., 2020). Schnell et al. (2018) and Tschopp et al. (2015) mentioned that characteristics of pneumothorax in chest X-rays usually present as a misalignment of visceral pleura and missing lung markings near the chest wall. If the size of the pneumothorax is large, a striking white line may be very apparent on the lung X-ray indicating the edge of a pleural lung. As air enters the pleural space, it separates the two pleura, presenting a noticeable white line, when it is actually the edge of the visceral pleura. Features like mediastinal shift, depressed hemidiaphragm, and wider intercostal space may indicate tension pneumothorax (Chen

and Guo, 2018).

In cases where the complexity of the pneumothorax is more severe and the number of abnormal lung lesions is high, using computed tomography (CT) will be very beneficial. CT scan is considered the gold standard in assessing diseases in the lung parenchyma due to its high sensitivity. It can detect the dimensions and estimate the size of pneumothorax, including small-sized pneumothorax that may be missed in chest X-rays. CT scan is the ideal diagnostic technique for patients suspected of SSP because it may reveal underlying bullous and parenchymal disorders, thus helping to establish treatment plans from the beginning. Early diagnosis of these respiratory illnesses may bring better outcomes for patients, as it allows the modification of treatment therapy, proper follow-up, and disease management that suits the needs of the patient personally. Despite the beneficial factors of CT, it is crucial to regulate radiation exposure in young patients to prevent additional complications and costs. Low-dose or ultra-low-dose thoracic CT is sufficient and can act as a better replacement for chest radiographs (Ruppert et al., 2020; Schnell et al., 2017).

Aside from the prior diagnostic tools, chest ultrasound is gaining popularity in pneumothorax diagnosis. Chest ultrasonography (USG) can present specific pneumothorax signs on a real-time basis, therefore simplifying the diagnosis process. It is an accepted modality for acute SP and is necessary for those with traumatic pneumothorax. Other advantages of using ultrasound are the minimal radiation dosage, cheap cost, and accessibility to bedside examination (Husain et al., 2012). Features of pneumothorax in USG according to Elhidsi, Antariksa and Sutoyo (2019) are missing lung sliding, lung pulse, and B-lines. On the other hand, the appearance of the lung point and stratosphere sign indicates pneumothorax. Regardless of its benefits, ultrasound's limitations may preclude it from being the most effective diagnostic tool for pneumothorax. Schnell et al. (2018) described these restrictions include patient features like obesity and inaccessible locations such as the subscapular region. The level of expertise of the examiner is also a critical factor in the quality of the ultrasonography and ultrasound is unable to determine the severity of the pneumothorax.

9. Management

9.1 Conservative Management

As recommended by the 2023 British Thoracic Society Guideline for Pleural Disease, facilities now prefer to treat pneumothorax depending on the patient's symptoms, rather than administering the same treatment for every patient. In individuals who do not have shortness of breath, hemodynamic issues, or compromised awareness, conservative management can be considered regardless of the SP size. This management normally takes 3 – 6 hours, before taking CXRs (Wong, Galiabovitch and Bhagwat, 2018). Observation may also be used in several asymptomatic large pneumothorax patients, albeit it takes around 48 hours to monitor disease progression in larger pneumothorax. Furthermore, if the patient begins to develop dyspnea while under observation, oxygen therapy may be provided to patients who do not suffer from oxygen sensitivity issues. The limitation of this therapy is that it cannot be given to SSP patients. Due to the complexity of the disease, it requires more intense intervention (Li et al., 2014).

9.2 Non-surgical Management

In stable SP patients with symptoms such as chest pain, breathlessness, and large pneumothorax, simple

aspiration can be administered. Wong, Galiabovitch and Bhagwat (2018) mentioned several methods that are available to be used for simple aspiration, the choices range from venous catheters to small-bore chest tubes. Among the methods, needle aspiration is known to be the most effective and is related to shorter hospital stays. According to Choi (2014), the success rate for treating PSP with aspiration reaches 75% and 35% for SSP patients. If the initial aspiration was unsuccessful, the management may continue by utilizing a tube thoracostomy (chest tube). According to Hassan et al. (2017), in SSP patient with large pneumothorax and PSP patient who fails to be treated with aspiration, intercostal chest drainage (ICD) can be done. In addition, Zulkifly and Singh (2022) support the statement above, mentioning that pneumothorax is one of the absolute indicators for the use of chest tubes. Initially, small-bore tubes are sufficient to achieve effective short-term outcomes. After monitoring, if there is pneumothorax size enlargement or subcutaneous emphysema, substitution to the large-bore chest tubes is required. Hassan et al (2017) also recommend that when air leaks continue or there is an absence of lung re-expansion after 48 hours, suction can be considered. Though the efficacy and evidence of success for suction are not yet clear and further investigation must be conducted.

In the non-surgical interventions for pulmonary diseases, chest physiotherapy and pulmonary rehabilitation exercises have demonstrated favorable outcomes in patient recovery. The Respiratory Physiotherapy Pocketbook, 3rd Edition (2020), emphasizes the importance of physiotherapy considerations for individuals with pneumothorax, prioritizing thoracic expansion exercises and mobility. The former involves maximal inspiration followed by relaxed expiration, promoting heightened air intake, expanding pulmonary capacity, and enhancing oxygen intake, as mentioned by Metin (2016). The latter encompasses activities demanding physical exertion to stimulate spontaneous deep breathing, elevate respiratory flow rates, and strengthen respiratory muscles, with examples including walking or stair climbing.

A study conducted by Çiftçi and Gezginaslan (2022) yielded positive outcomes in the application of pulmonary rehabilitation for patients with SSP. Their research demonstrated a significant reduction in the duration of tube drainage and hospital stay among individuals employing both bronchial hygiene and respiratory retaining techniques, as opposed to those undergoing only one of the treatments. The former technique comprises forced expiration, active breathing cycles, positive expiratory pressure, postural drainage, and percussion or vibration techniques. The latter involves pursed lip breathing, lateral costal breathing, diaphragmatic breathing, slow and deep breathing, and frog breathing.

9.3 Surgical Management

When other management options have failed or when the patient shows a desire to undergo operations, pneumothorax may be treated surgically. Patients who are prepared and willing to undergo the lengthy treatment, as well as those who have considered modifying their lifestyle, will be eligible for surgery. Specific conditions where surgical management for pneumothorax must be considered include second ipsilateral pneumothorax, first contralateral pneumothorax, synchronous bilateral SP, spontaneous haemothorax, at-risk professions (e.g. pilots and divers), and pregnancy (Wong, Galiabovitch and Bhagwat, 2018). In addition, Schnell et al. (2018) mentioned that if there is a failure of lung re-expansion or persistent air leak (PAL) for over 48 hours, more invasive intervention should be done. Kusmatuti and Marhana (2019) recommend the use of video-assisted thoracic surgery (VATS) with the addition of pleurodesis for treating pneumothorax. After eliminating blebs or bulla with VATS and pleurodesis, the recurrence rate of pneumothorax

only reaches 5.4%. Moreover, the treatment is associated with lower costs, less invasiveness, shorter hospital stay, and a less painful healing process, therefore making it an excellent choice for therapy (Hassan et al., 2017; Tschopp et al., 2015). Another option that can be considered when VATS is unavailable is open thoracotomy. It involves making an incision into the pleural space from the chest to get access to a thoracic organ, most commonly the heart or lungs (Lazopoulos et al., 2015). Post-operative care for thoracotomy must be done carefully and thoroughly because the patient may suffer from respiratory arrest, thus leading to higher medical expenditures. Although thoracotomy with pleurectomy prevents most recurrences of the other procedures, it should be considered as a last alternative due to the high risk of complications (Vuong et al., 2018).

10. Conclusion

Spontaneous pneumothorax remains as one of the complications associated with lung diseases, which can significantly impacting patients' quality of life. Understanding the specifics and effective management of the condition holds the potential to provide positive outcomes. As a suggestion for further research, the study identifies opportunities for exploration, such as the need for more in-depth investigations into diagnostic tools, risk factors, and personalized management strategies. Additionally, collaborative efforts among international healthcare communities is recommended to establish a unified and effective approach to spontaneous pneumothorax.

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References

- McKnight CL, Burns B. Pneumothorax [Internet]. PubMed. Treasure Island (FL): StatPearls Publishing; 2022 [cited 2022 Jun 3]. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK441885/?report=classic>
- Onuki T, Ueda S, Yamaoka M, Sekiya Y, Yamada H, Kawakami N, et al. Primary and Secondary Spontaneous Pneumothorax: Prevalence, Clinical Features, and In-Hospital Mortality. *Canadian Respiratory Journal* [Internet]. 2017 [cited 2019 Oct 11];2017(6014967):1–8. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5366759/#!po=8.33333>
- Costumbrado J, Ghassemzadeh S. Pneumothorax, Spontaneous [Internet]. PubMed. Treasure Island (FL): StatPearls Publishing; 2020 [cited 2022 Jun 23]. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK459302/>
- Papagiannis A, Lazaridis G, Zarogoulidis K, Papaiwannou A, Karavergou A, Lampaki S, et al. Pneumothorax: an up to date “introduction.” *Annals of Translational Medicine* [Internet]. 2015 Mar 1 [cited 2020 Feb 19];3(4). Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4381472/>
- Huan NC, Sidhu C, Thomas R. Pneumothorax Classification and Etiology. *Clinics in Chest Medicine*. 2021 Dec;42(4):711–27.
- Hallifax RJ, Goldacre R, Landray MJ, Rahman NM, Goldacre MJ. Trends in the Incidence and Recurrence of Inpatient-Treated Spontaneous Pneumothorax, 1968-2016. *JAMA*. 2018 Oct 9;320(14):1471.

- Bobbio A, Dechartres A, Bouam S, Damotte D, Rabbat A, Regnard JF ., et al. Epidemiology of spontaneous pneumothorax: gender-related differences. *Thorax* [Internet]. 2015 Apr 27;70(7):653–8. Available from: <https://thorax.bmj.com/content/70/7/653>
- Gayatri Devi Y, Usharani N, Premkumar A, Sambasivarao G, Kumari VS, Joshua S. Clinical Profile of Spontaneous Pneumothorax in Adults: A Retrospective Study. *The Indian Journal of Chest Diseases & Allied Sciences* [Internet]. 2015 Oct 1 [cited 2022 Oct 2];57(4):219–23. Available from: <https://pubmed.ncbi.nlm.nih.gov/27164729/>
- Ince A, Ozucelik DN, Avci A, Nizam O, Dogan H, Topal MA. Management of Pneumothorax in Emergency Medicine Departments: Multicenter Trial. *Iranian Red Crescent Medical Journal*. 2013 Dec 5;15(12).
- Choi WI. Pneumothorax. *Tuberculosis and Respiratory Diseases* [Internet]. 2014;76(3):99. Available from: <https://synapse.koreamed.org/DOIx.php?id=10.4046/trd.2014.76.3.99>
- Brown SGA, Ball EL, Macdonald SPJ, Wright C, McD Taylor D. Spontaneous pneumothorax; a multicentre retrospective analysis of emergency treatment, complications and outcomes. *Internal Medicine Journal*. 2014 May;44(5):450–7.
- Schnell J, Koryllos A, Lopez-Pastorini A, Lefering R, Stoelben E. Spontaneous Pneumothorax: Epidemiology and Treatment in Germany Between 2011 and 2015. *Deutsches Aerzteblatt Online*. 2017 Nov 3;114:739–44.
- MacDuff A, Arnold A, Harvey J. Management of Spontaneous Pneumothorax: British Thoracic Society Pleural Disease Guideline 2010. *Thorax*. 2010 Aug 1;65(Suppl 2):ii18–31.
- Kepka S, Dalphin JC, Pretalli JB, Parmentier AL, Lauque D, Trebes G, et al. How spontaneous pneumothorax is managed in emergency departments: a French multicentre descriptive study. *BMC Emergency Medicine*. 2019 Jan 11;19(1).
- Schnell J, Beer M, Eggeling S, Gesierich W, Gottlieb J, Herth Felix JF, et al. Management of Spontaneous Pneumothorax and Post-Interventional Pneumothorax: German S3 Guideline. *Respiration*. 2018 Jul 24;97(4):370–402.
- Tschopp JM, Bintliffe O, Astoul P, Canalis E, Driesen P, Janssen J, et al. ERS task force statement: diagnosis and treatment of primary spontaneous pneumothorax. *European Respiratory Journal*. 2015 Jun 25;46(2):321–35.
- Roberts, M.E., Rahman, N.M., Maskell, N.A., Bibby, A.C., Blyth, K.G., Corcoran, J.P., Edey, A., Evison, M., Duneesha De Fonseka, Hallifax, R., Harden, S., Lawrie, I., Lim, E., McCracken, D.J., Mercer, R., Mishra, E.K., Nicholson, A.G., Farinaz Noorzad, Opstad, K. and Parsonage, M. (2023). British Thoracic Society Guideline for pleural disease. *Thorax*, 78(Suppl 3), pp.s1–s42. doi:<https://doi.org/10.1136/thorax-2022-219784>.
- Ruppert AM, Sroussi D, Khallil A, Giot M, Assouad J, Cadranel J, et al. Detection of secondary causes of spontaneous pneumothorax: Comparison between computed tomography and chest X-ray. *Diagnostic and Interventional Imaging*. 2020 Apr;101(4):217–24.
- Salik, I., Vashisht, R. and Abramowicz, A.E. (2020). *Bronchopleural Fistula*. [online] PubMed. Available at: <https://www.ncbi.nlm.nih.gov/books/NBK534765/>.
- Husain L, Wayman D, Carmody K, Hagopian L, Baker W. Sonographic diagnosis of pneumothorax. *Journal of Emergencies, Trauma, and Shock*. 2012;5(1):76.
- Chen Y, Guo Z. Unusual case of primary spontaneous hemopneumothorax in a young man with atypical tension pneumothorax: a case report. *Journal of Medical Case Reports*. 2018 Jul 2;12(1).

- Elhidsi M, Antariksa B, Sutoyo DK. The Role of Thoracic Ultrasound in Diagnosing Pneumothorax. *Jurnal Respirologi Indonesia*. 2019 Mar 28;38(4):239–43.
- Zarogoulidis P, Kioumis I, Pitsiou G, Porpodis K, Lampaki S, Papaiwannou A, et al. Pneumothorax: from definition to diagnosis and treatment. *Journal of Thoracic Disease* [Internet]. 2014 Oct 1;6(Suppl 4):S372–6. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4203989/>
- Li Z, Huang H, Li Q, Zarogoulidis K, Kougioumtzi I, Dryllis G, et al. Pneumothorax: observation. *Journal of thoracic disease* [Internet]. 2014 [cited 2022 May 8];6(Suppl 4):S421-6. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4203987/>
- Hassan M, Talwar A, Hallifax RJ, Corcoran JP, Psallidas I, Rahman NM. Tips and tricks in the management of pneumothorax: an update. *Minerva Respiratory Medicine*. 2017 Oct;56(4).
- Wong A, Galiabovitch E, Bhagwat K. Management of primary spontaneous pneumothorax: a review. *ANZ Journal of Surgery*. 2018 Jul 5;89(4):303–8.
- Zulkifly S, Singh G. Pulmonologi Intervensi Dasar. *Indonesia Journal of Chest Critical and Emergency Medicine* [Internet]. 2022 Jul 13 [cited 2022 Oct 31];9(1). Available from: <http://www.indonesiajournalchest.com/index.php/IJC/issue/view/206/Pulmonologi%20Intervensi%20Dasar>
- Kusmatuti Y, Marhana IA. Seorang Perempuan Perokok Tembakau dan Mariyuana dengan Pneumotoraks Spontan Primer Akibat Blep Multipel yang Pecah. *Jurnal Respirasi*. 2019 Apr 1;1(2):53.
- Lazopoulos A, Barbetakis N, Lazaridis G, Baka S, Mpoukovinas I, Karavasilis V, et al. Open thoracotomy for pneumothorax. *Journal of Thoracic Disease* [Internet]. 2015 Feb 1 [cited 2020 May 11];7(Suppl 1):S50–5. Available from: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4332106/>
- Vuong NL, Elshafay A, Thao LP, Abdalla AR, Mohyeldin IA, Elsabaa K, et al. Efficacy of treatments in primary spontaneous pneumothorax: A systematic review and network meta-analysis of randomized clinical trials. *Respiratory Medicine*. 2018 Mar 5;137:152–66.
- Widjaya DP, Amin Z, Suprayitno, Afifi R, Shatri H. Karakteristik dan Faktor-Faktor yang Mempengaruhi Kesintasan Pasien Pneumotoraks di Rumah Sakit Cipto Mangunkusumo, Jakarta. *Indonesian Journal of CHEST Critical and Emergency Medicine* [Internet]. 2014 Aug 4 [cited 2022 Jun 16];1(3). Available from: <https://www.indonesiajournalchest.com/index.php/IJC/issue/view/17>
- World Health Organisation. ICD-11 [Internet]. Who.int. 2019. Available from: <https://icd.who.int/en>
- Metin B. Comparison of different respiratory exercise methods in patients with chest tubes for spontaneous pneumothorax. *The Turkish Journal of Thoracic and Cardiovascular Surgery*. 2016 Oct 31;24(4):717–21.
- Çiftçi H, Gezginaslan Ö. Effectiveness of Pulmonary Rehabilitation in Secondary Spontaneous Pneumothorax Patients. *Eastern Journal Of Medicine*. 2022;27(1):72–6.
- Cross J, Mary-Ann Broad, Quint M, Ritson P, Thomas S. *Respiratory physiotherapy pocketbook : an on call survival guide*. Edinburgh: Elsevier; 2020.
- Mummadi SR, Stoller JK, Lopez R, Kailasam K, Gillespie CT, Hahn PY. Epidemiology of Adult Pleural Disease in the United States. *Chest*. 2021 Oct;160(4):1534–51.