

## Review

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# Diagnosis and Management of Spontaneous Pneumothorax in the Emergency Department: A Review of the Most Current Clinical Evidence for Diagnosis and Treatment

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## ABSTRACT

**Background:** Spontaneous non-traumatic pneumothorax is a relatively common clinical presentation in the Emergency Department. The diagnosis of spontaneous non-traumatic pneumothorax has evolved from basic chest radiography to the reference standard of CT imaging. Point-of-care ultrasound is another highly sensitive diagnostic modality that has gained increasing acceptance. Finally, the treatment of this type of pneumothorax has also been rapidly changing.

**Objective:** We give an overview of the current literature regarding the definition and classification for pneumothorax. We discuss the current methods of diagnosis and management of spontaneous non-traumatic pneumothorax, which now include the promising treatment alternative of smaller pigtail thoracostomy catheters. We also discuss how a rapidly placed smaller pigtail catheter may be a viable single management option for a spontaneous tension pneumothorax.

**Discussion:** The management of spontaneous non-traumatic pneumothorax has been rapidly advancing. Viable treatment options now include observation alone, needle aspiration and placement of a small pigtail thoracostomy catheter, in addition to the use of a traditional thoracostomy tube.

**Conclusion:** Although the traditional treatment for a spontaneous non-traumatic pneumothorax was placement of a larger thoracostomy tube, this may no longer be the optimal management approach in these patients. The use of smaller pigtail thoracostomy catheters provides a viable treatment alternative to these larger catheters, and may also be used effectively as the only treatment step in a spontaneous tension pneumothorax. Placement of these smaller catheters sets the stage for potential outpatient management of pneumothorax, with increased comfort for the patient and possible cost savings.

**KEYWORDS:** Spontaneous pneumothorax; Primary pneumothorax; Tension pneumothorax; Pneumothorax; Pigtail catheter; Mini-catheter; Thoracostomy; Needle aspiration; Observation; Chest tube; Emergency department.

## INTRODUCTION

Spontaneous non-traumatic pneumothorax (PTX) is a relatively common clinical problem in the Emergency Department (ED).<sup>1</sup> Interestingly, there is currently considerable variation in clinical practice with regard to the management of PTX.<sup>2,3</sup> In this article, we review the most

current clinical evidence regarding the diagnosis and treatment of non-traumatic PTX in the ED.

### Categories of Pneumothorax

A PTX is classified into a few categories based on the etiology: spontaneous, traumatic or iatrogenic. A spontaneous PTX can further be classified as primary or secondary (Table 1).

A primary spontaneous PTX occurs in patients without previously diagnosed pulmonary disease, when weakened architecture of the lung allows for sudden rupture of the visceral pleura. This leads to a loss of the negative pressure of -5 mm Hg normally found in the pleural space, with resulting accumulation of air between the normally tightly opposed layers of the parietal and visceral pleura.<sup>4</sup> Primary spontaneous PTX occurs in 7.4 to 18 cases per 100,000 population per year in men and in 1.2 to 6 cases per 100,000 population per year in women.<sup>5</sup> Smoking cigarettes or drugs, and a taller, thin physique are risk factors for developing primary spontaneous PTX in men.<sup>6,7</sup>

A secondary spontaneous PTX often results from an underlying disease process in the lungs, such as chronic obstructive pulmonary disease.<sup>5</sup> This accounts for one-third of cases of spontaneous PTX.<sup>4</sup> The incidence is 6.3 cases per 100,000 each year among men, and 2.0 cases per 100,000 each year among women.<sup>5</sup> The peak incidence of secondary spontaneous PTX occurs in patients between the ages of 60 to 65.<sup>5</sup>

A PTX can be further characterized as a ‘tension PTX’ when progressive accumulation of air leads to a corresponding increase in intrathoracic pressure. A tension PTX may occur in cases where there is a ‘ball-valve effect’ within the lung, allowing air to flow out into the chest cavity without allowing re-entry. The resultant increased intrathoracic pressure causes under-filling of the right side of the heart, due to limitation of venous blood return from the vena cavae.<sup>8</sup> Tension PTX is clinically recognized when evidence of hemodynamic instability is present, with findings that may include tachycardia, tachypnea, hypoxia and hypotension. Tracheal deviation away from the affected side may also be recognized.<sup>4,9</sup>

### Diagnosis of Spontaneous Pneumothorax

ECG changes from a PTX are a common finding.<sup>10</sup> Lowered QRS voltage has been noted in lead I as a possible sign of a PTX.<sup>11</sup> In one study, 40% of the study group with a PTX on the

right side had lowered QRS voltage and 70% of the study group with a PTX on the left side had lowered QRS voltage.<sup>11</sup>

CXR is often utilized for the initial diagnosis of PTX, due to its comparative low cost and easy obtainability at the patient’s bedside. The traditional standard for PTX evaluation is with an expiratory, upright CXR.<sup>12</sup> Limiting the sensitivity of this test, a large PTX that layers anteriorly may potentially be missed in a supine patient who cannot sit upright.

Chest CT, which is considered the gold standard in the diagnosis of PTX, has a much higher sensitivity as compared to CXR.<sup>13-15</sup> The pooled sensitivity and specificity for CXR were shown in one study to be 31.8% and 100% (respectively) when compared with chest CT.<sup>16</sup> Chest CT scan has the ability to image the chest in 3-dimensions, thus easily detecting a PTX of any size within all locations of the thoracic cavity. A PTX that is missed on CXR, but seen on CT scan, has defined the term occult PTX in the modern literature. The incidence of occult PTX ranges from 3.7% to 64%.<sup>17</sup> The occult PTX that is relatively small in size is often clinically less important, as many sources urge no intervention for this finding.<sup>13,17,18</sup> However, especially when a supine CXR is used for diagnosis, a relatively large PTX that requires emergent treatment may not be adequately visualized. CT scan can be especially helpful in diagnosing these types of PTX.

Though CT scan has an excellent sensitivity in diagnosing PTX, point-of-care ultrasound (US) has emerged as a rapid and accurate bedside technique for the diagnosis of PTX because of its relative ease of use and lack of radiation. US has been shown in multiple studies to be far superior to a supine CXR for PTX. A recent meta-analysis of US for PTX demonstrated a sensitivity of 95.3%, a specificity of 91.1%, and a negative predictive value of 100%.<sup>19,20</sup> In 1986, the absence of “lung sliding” was noted in animals with PTX.<sup>21</sup> This was successfully applied to human patients in 1995.<sup>20</sup> Lung sliding refers to the back and forth respiratory movement of the normally tightly opposed visceral and parietal pleura of the lung that is seen on US. This pleural line can be visualized just beneath the level of the ribs and is best appreciated using a high frequency linear probe. Because the US probe is placed anteriorly at the more superior aspect of the supine patient’s chest, a PTX that collects anteriorly and is difficult to see on CXR can be well visualized on US. The probe can then be moved more laterally and inferiorly to assess the size of the PTX. A large PTX will result in a lack of lung sliding at both positions, while a smaller one may result in

Pneumothorax Classifications
Spontaneous pneumothorax <ul style="list-style-type: none"> <li>• Primary: secondary to rupture in the subpleural lining of the lung in a patient without any previously diagnosed lung disease</li> <li>• Secondary: secondary to pre-existing pulmonary disease</li> </ul>
Traumatic pneumothorax: resulting from penetrating or blunt trauma to the chest
Iatrogenic: due to a medical intervention

Table 1: Classification of pneumothorax.<sup>5,13</sup>

a lack of sliding anteriorly with sliding preserved laterally.

In addition to lung sliding, normal respiratory movement of the lung creates comet-tail artifacts, which are vertical hyperechoic (bright) lines that arise from the normal pleural line and extend a short distance towards the bottom of the image.<sup>22</sup> The accumulation of intrathoracic air in a PTX splits the normally tightly opposed pleural visceral and parietal layers. This leads to the disappearance of both normal lung sliding and comet-tail artifacts.

Of note, it should be known that there are several circumstances in which one may detect the absence of lung sliding on US when in fact there is no PTX, leading to a potentially false positive examination. This may occur in patients with large bullae in the setting of chronic obstructive pulmonary disease. Lung sliding will also not be appreciated in patients with adhesions, such as in patients who have undergone prior lung surgery or pleurodesis. Finally, patients with large pleural effusions, where fluid disrupts the interface between the normally opposed visceral and parietal pleura, will also not have appreciable lung sliding on US. Caution should be taken when using US to assess for the presence of PTX in these patients.<sup>23</sup>

#### Management Options for Spontaneous Pneumothorax

The treatment of spontaneous PTX is largely dependent on the patient's clinical presentation. If the patient is stable and has less than 15-20% involvement of the hemithorax, observation without intervention may be appropriate.<sup>13,24</sup> The British Thoracic Society additionally recommends that the patient must not exhibit any dyspnea to qualify for observation alone.<sup>25</sup> A PTX is reabsorbed at a rate of 1-2% per day, which may be accelerated by the administration of supplemental high flow oxygen.<sup>26,27</sup>

For a stable patient with a spontaneous PTX involving greater than 15-20% of the hemithorax, there is controversy with regard to the management options. These include observation alone (usually in the hospital for a period of time), needle aspiration, placement of a smaller thoracostomy catheter or insertion of a standard chest tube. More recent literature has focused on treatment with smaller pigtail thoracostomy tubes (typically 8-9

French size), a much more comfortable option for the patient. This also allows for increased mobility and sets the stage for potential outpatient management of PTX. A summary of treatment guidelines for subtypes of pneumothorax is listed in Table 2.

The literature supporting specific management of PTX has been evolving rapidly in the recent years. A systematic review of the literature by Brims and Maskell in 2013 identified 18 studies with a total of 1235 patients. Of these, 992 cases were identified as spontaneous PTX. The success of treatment with smaller catheters attached to Heimlich flutter valves was 1060/1235 (85.8%). Outpatient treatment was possible in 761/977 (77.9%). Complications were rare.<sup>28</sup> In a 2014 article by Voisin et al<sup>2</sup>, 132 patients with spontaneous PTX were managed as outpatients with a pigtail thoracostomy tube attached to a Heimlich flutter valve. Of these 132 patients, 110 had primary PTX and 22 had secondary PTX. 103 of the 132 patients were exclusively managed as outpatients, with the ambulatory success rate of 78%. 7 patients were initially admitted but then quickly discharged, bringing the success rate to 83%. Of these 7 patients; 2 were observed as they were the first patients to be treated with pigtail catheters, 2 had severe dyspnea and COPD requiring hospital observation and 1 had chest pain requiring additional evaluation. Furthermore, in the author's opinion, 3 patients were unnecessarily admitted.<sup>2</sup> Of all patients, 26% had recurrence at 1 year. The authors describe a significant cost savings with outpatient management: \$926 versus \$4,276 with placement of a chest tube and admission to the hospital for a significant period of time (typically 4 days in this study).

Finally, a 2014 study by Massongo et al enrolled 60 patients with primary spontaneous PTX. Of these, 20% were characterized as small and all were successfully managed with observation alone.<sup>29</sup> In the remaining 80% that were characterized as large, all patients underwent placement of a smaller 8.5 French pigtail catheter.<sup>29</sup> 79.2% of these patients were successfully managed with the catheter alone.<sup>29</sup> 20.8% of the patients went on to require video-assisted thoracoscopy for definitive management of the PTX.<sup>29</sup> These studies make the strong argument for the management of hemodynamically stable patients with spontaneous PTX, even of a larger size, as outpatients with a smaller thoracostomy tube attached to a Heimlich valve.

Pneumothorax Size (% of hemithorax)	Interventions with Options
<15-20%	Observation and oxygen
≥20% (asymptomatic)	1) Pigtail catheter placement 2) Needle aspiration
≥20% (symptomatic)	1) Pigtail catheter placement 2) Chest tube placement
Tension pneumothorax	1) Immediate needle decompression then followed by placement of pigtail catheter or chest tube 2) Immediate pigtail catheter placement 3) Immediate chest tube placement
Pneumothorax with hemothorax	Chest tube placement

Table 2: Treatment guidelines for subtypes of pneumothorax.<sup>13,25,33</sup>

An alternative management strategy is needle aspiration using an intravenous catheter.<sup>4,13</sup> Air aspiration has been shown to be a relatively effective treatment option as compared to chest tube drainage for the first episode of a primary spontaneous PTX.<sup>1,13,30-32</sup> 30-80% of these patients may be successfully treated (defined as requiring no additional invasive intervention) with the aspiration technique alone.<sup>33</sup> Patient treated with catheter aspiration require a period of hospital observation, with a repeat CXR at 6 hours. If the patient is clinically improving and the PTX has significantly decreased in size, they may be discharged. However, as compared to a first time spontaneous PTX, recurrent PTX is best managed with a thoracostomy tube. In these patients, repeated needle aspiration is less likely to be successful.<sup>25</sup>

The management of first time PTX measuring greater than 20% of the hemithorax is therefore controversial.<sup>34</sup> There have been several studies comparing these treatment modalities.<sup>1,31,35,36</sup> Based on a systematic review and meta-analysis of these articles by Aguinalde et al, a thoracostomy tube may be more effective in the immediate post-treatment period. However, after 1 week this advantage ceases to exist.<sup>37</sup> Currently, the British Thoracic Society currently recommends needle aspiration as the first line of action for a symptomatic and larger spontaneous PTX. Advantages of needle aspiration include less pain than chest tube insertion, less material and human resources, and potential reduction in hospitalization and hospital length of stay.<sup>25,37</sup> Unfortunately, needle aspiration is associated with a failure in one-third of patients, and repeat needle aspiration is unlikely to be successful unless associated with an initial technical difficulty.<sup>25</sup> Therefore, the current guidelines of the American

College of Chest Physicians advocate for the use of a smaller thoracostomy catheter over aspiration.<sup>37,38</sup> Table 3 summarizes studies to date on management of PTX.

For management of a tension PTX, and especially if associated with hemodynamic instability, it has been recommended that the patient undergo immediate large bore needle chest decompression.<sup>39</sup> Because needle decompression is only a temporary measure which may have variable success, the patient will then typically require placement of a thoracostomy tube for definitive management of the PTX.<sup>13</sup> Immediate placement of a smaller thoracostomy catheter is a viable single step alternative to needle decompression, if this can be done expeditiously.

### METHODOLOGY OF TREATMENT OF SPONTANEOUS PNEUMOTHORAX

#### Pigtail Thoracostomy Tube Placement

Use of smaller pigtail thoracostomy catheters is an increasingly important and effective treatment option for the management of spontaneous PTX, even with tension physiology.<sup>2,38</sup> To place a pigtail catheter, one can use a commercial catheter kit that is readily available in most hospitals. These kits employ the Seldinger technique to place a 8-9 French thoracostomy tube. The most common insertion site is at the second intercostal space along the mid-clavicular line. Alternatively, a second position is at the same location for traditional chest tubes (fourth or fifth intercostal space along the anterior axillary line). The technique for thoracostomy tube catheter placement will be familiar to most clinicians, as using the Seldinger technique will make this

Study	Population	#Patients	Outcome	Success rate			
				Intervention	Aspiration	Pigtail	Chest tube
Ayed 2006 RCT <sup>30</sup>	PSP symptomatic or >20% size	137	Re-expansion at 1 wk		89%		88%
Massongo 2013 POS <sup>44</sup>	PSP: small undergo observation alone, large/dyspnea	60	Re-expansion at 1 wk	100%		83%	
Parlak 2012 PRT <sup>45</sup>	PSP symptomatic or >20% size	56	Immediate re-expansion		68%		80%
Voisin 2014 RR <sup>2</sup>	Large PSP and SSP	132	Outpt management at day 4			78%	
Harvey 1994 PRT <sup>34</sup>	PSP	73	1 yr recurrence		86%		74%
Brown 2014 RC <sup>43</sup>	PSP and SSP	323	1 yr recurrence	95%			83%
Ho 2010 RCT <sup>46</sup>	PSP	48	Re-expansion at 1 wk		91%	88%	
Kelly 2008 RC <sup>24</sup>	PSP	154	Need for additional intervention	79%	50%		73%
Noppen 2002 RCT <sup>1</sup>	PSP	60	Re-expansion at 1 wk		93%		85%

RCT: Randomized Control Trial; POS: Prospective observational Study; PRT: Prospective Randomized Trial; RR: Retrospective Review; RC: Retrospective Cohort; PSP: Primary Spontaneous Pneumothorax; SSP: Secondary Spontaneous Pneumothorax.

**Table 3:** Comprehensive summary of studies to date on pneumothorax management.

very similar to placement of a central line.

A Pleurovac chest tube drainage system is most commonly used for the initial removal of air from the thoracic cavity. Make sure to cut the tip of the long plastic tubing that comes off the Pleurovac, so that the adaptor can be easily inserted. Apply tape to both the Pleurovac tubing and the adaptor to prevent air leaks. The plastic adaptor is then connected to a 3-way stopcock. Last, the pigtail thoracostomy catheter is connected to the stopcock to complete the drainage system.

Gentle wall suction through the pleural drainage device is often used to initially inflate the lung. Once the lung has been adequately inflated, the tube can be placed to water seal. A Heimlich valve may alternatively be utilized in place of a water-seal device.<sup>13</sup> A less common, but potentially effective method for lung re-inflation, is to attach the thoracostomy catheter to a 3-way stopcock, and then to slowly aspirate the air from the chest. Confirm the tube placement and change in PTX size after treatment with a CXR.

#### Needle Aspiration

The British Thoracic Society advises needle aspiration for initial treatment of a spontaneous PTX and is an alternative approach to placement of a thoracostomy catheter.<sup>25</sup> For needle aspiration, a 16 French angiocatheter is used. Insertion sites are similar to those used for pigtail thoracostomy tube placement. After infiltration of local anesthetic, the angiocatheter is inserted while also aspirating with a syringe. Once air is withdrawn, the catheter is then advanced while the needle is simultaneously withdrawn. When the catheter is in adequate position, air can then be manually aspirated using a 3-way stopcock. Another strategy is to connect the catheter to a vacuum bottle with a water seal that generates a negative pressure. The vacuum bottle is connected until there is no further air bubbling in the bottle for 30 minutes.<sup>31</sup> Of note, aspiration should be stopped if more than 2.5 liters of air have been removed, as this suggests that further lung expansion is unlikely.<sup>1,25</sup> If there is complete re-expansion, or only a small rim of apical PTX on repeat CXR, the procedure is complete. If the lung is not significantly expanded and the procedure was technically successful, consider placement of a pigtail thoracostomy catheter.

#### Prophylactic Antibiotics

The use of prophylactic antibiotics is controversial.<sup>40</sup> There is no consensus on the use of prophylactic antibiotics after thoracostomy catheter placement in the ED. The rate of empyema from chest tube insertion is estimated to be 1%.<sup>41</sup> Some data suggests that antibiotics may reduce the incidence of pneumonia or empyema associated with thoracostomy tubes.<sup>42</sup> If the decision is made to utilize antibiotics, first generation cephalosporins administered for the first 24 hours are recommended (although it should be noted that this recommendation was created in the setting of a hemothorax).<sup>43</sup> However, there is also data suggesting

that prophylactic antibiotics are unnecessary.<sup>42</sup> Regardless of the decision on prophylactic antibiotics, sterile technique should be the priority during placement of a thoracostomy catheter.<sup>41</sup>

#### CONCLUSION

In this article, we have reviewed the definition and classifications for PTX. We have also focused on the most current diagnosis and management of primary spontaneous PTX, so that clinicians will have the latest information to optimize patient care. As treatment of PTX evolves, there is currently no set standard for the treatment of primary PTX. American and British Thoracic Society recommendations differ from simple needle aspiration to placement of a small-bore thoracostomy tube. These smaller pigtail thoracostomy catheters present a promising treatment alternative to traditional larger chest tubes, even in a tension PTX. Outpatient management of hemodynamically stable patients with primary spontaneous non-traumatic PTX has now become a viable management option with potential treatment benefits and cost savings.

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#### REFERENCES

1. Noppen M, Alexander P, Driesen P, Slabbynck H, Verstraeten A. Manual aspiration versus chest tube drainage in first episodes of primary spontaneous pneumothorax: a multicenter, prospective, randomized pilot study. *Am J Respir Crit Care Med*, 2002; 165(9): 1240-1244. doi: [10.1164/rccm.200111-078OC](https://doi.org/10.1164/rccm.200111-078OC)
2. Voisin F, Sohier L, Rochas Y, et al. Ambulatory management of large spontaneous pneumothorax with pigtail catheters. *Ann Emerg Med*. 2014; 64(3): 222-228. doi: [10.1016/j.annemergmed.2013.12.017](https://doi.org/10.1016/j.annemergmed.2013.12.017)
3. Lichtenstein DA, Mezière G, Lascols N, et al. Ultrasound diagnosis of occult pneumothorax. *Crit Care Med*. 2005; 33(6): 1231-1238. doi: [10.1097/01.CCM.0000164542.86954.B4](https://doi.org/10.1097/01.CCM.0000164542.86954.B4)
4. Manthey DE, Nicks BA. Pneumothorax. In: Adams JG, Barton ED, Collings JL, DeBlieux PM, Gisoni MA, Nadel ES, eds. *Emergency Medicine: Clinical Essentials*. 2<sup>nd</sup> ed., Elsevier; 2013: 423-430.
5. Sahn SA, Heffner JE. Spontaneous Pneumothorax. *N Engl J Med*. 2000; 342: 868-874. doi: [10.1056/NEJM200003233421207](https://doi.org/10.1056/NEJM200003233421207)
6. Hobbs BD, Foreman MG, Bowler R, et al. Pneumothorax risk factors in smokers with and without chronic obstructive pulmonary disease. *Ann Am Thorac Soc*. 2014; 11: 1387-1394. doi: [10.1513/AnnalsATS.201405-224OC](https://doi.org/10.1513/AnnalsATS.201405-224OC)
7. Luh S. Review: Diagnosis and treatment of primary spontaneous pneumothorax. *J Zhejiang Univ Sci B*. 2010; 11(10): 735-

744. doi: [10.1631/jzus.B1000131](https://doi.org/10.1631/jzus.B1000131)
8. Simpson G, Vincent S, Ferns J. Spontaneous tension pneumothorax: what is it and does it exist? *Intern Med J.* 2012; 42(10): 1157-1160. doi: [10.1111/j.1445-5994.2012.02910.x](https://doi.org/10.1111/j.1445-5994.2012.02910.x)
9. Yoon JS, Choi SY, Suh JH, et al. Tension pneumothorax, is it a really life-threatening condition? *J Cardiothorac Surg.* 2013; 8: 197. doi: [10.1186/1749-8090-8-197](https://doi.org/10.1186/1749-8090-8-197)
10. Krenke R, Nasilowski J, Przybylowski T, Chazan R. Electrocardiographic changes in patients with spontaneous pneumothorax. *J Physiol Pharmacol.* 2008;59 Suppl 6: 361-373.
11. Armen RN, Frank TV. Electrocardiographic patterns in pneumothorax. *Dis Chest.* 1949; 15: 709-719.
12. Beres RA, Goodman LR. Pneumothorax: detection with upright versus decubitus radiography. *Radiology.* 1993; 186(1): 19-22. doi: [10.1148/radiology.186.1.8416563](https://doi.org/10.1148/radiology.186.1.8416563)
13. Kosowsky JM, Kimberly HH. Pleural Disease. In: Marx JA, Hockberger RS, Walls RM, eds. *Rosen's Emergency Medicine - Concepts and Clinical Practice.* 2-Volume Set. 8<sup>th</sup> ed., Elseiver; 2013: 988-996.
14. Ball CG, Kirkpatrick AW, Laupland KB, et al. Incidence, risk factors, and outcomes for occult pneumothoraces in victims of major trauma. *J Trauma.* 2005; 59: 917-924; discussion 924-925.
15. Ding W, Shen Y, Yang J, He X, Zhang M. Diagnosis of pneumothorax by radiography and ultrasonography: A meta-analysis. *Chest.* 2011; 140: 859-866. doi: [10.1378/chest.10-2946](https://doi.org/10.1378/chest.10-2946)
16. Nagarsheth K, Kurek S. Ultrasound detection of pneumothorax compared with chest X-ray and computed tomography scan. *Am Surg.* 2011; 77: 480-484.
17. Omar HR, Abdelmalak H, Mangar D, Rashad R, Helal E, Camporesi EM. Occult pneumothorax, revisited. *J Trauma Manag Outcomes.* 2010; 4: 12. doi: [10.1186/1752-2897-4-12](https://doi.org/10.1186/1752-2897-4-12)
18. Mowery NT, Gunter OL, Collier BR, et al. Practice management guidelines for management of hemothorax and occult pneumothorax. *J Trauma.* 2011; 70(2): 510-518. doi: [10.1097/TA.0b013e31820b5c31](https://doi.org/10.1097/TA.0b013e31820b5c31)
19. Raja AS, Jacobus CH. How accurate is ultrasonography for excluding pneumothorax? *Ann Emerg Med.* 2013; 61(2): 207-208. doi: [10.1016/j.annemergmed.2012.07.005](https://doi.org/10.1016/j.annemergmed.2012.07.005)
20. Lichtenstein D, Menu Y. Lung Sliding. *Chest.* 1995; 108: 1345-1348.
21. Rantanen NW. Diseases of the thorax. *Vet Clin North Am Equine Pract.* 1986; 2: 49-66.
22. Lichtenstein D, Mezière G, Biderman P, Gepner A. The comet-tail artifact: an ultrasound sign ruling out pneumothorax. *Intensive Care Med.* 1999; 25(4): 383-388.
23. Volpicelli G, Elbarbary M, Blaivas M, et al. International evidence-based recommendations for point-of-care lung ultrasound. *Intensive Care Med.* 2012; 38(4): 577-591. doi:[10.1007/s00134-012-2513-4](https://doi.org/10.1007/s00134-012-2513-4)
24. Kelly A-M, Druda D. Comparison of size classification of primary spontaneous pneumothorax by three international guidelines: a case for international consensus? *Respir Med.* 2008; 102: 1830-1832. doi: [10.1016/j.rmed.2008.07.026](https://doi.org/10.1016/j.rmed.2008.07.026)
25. MacDuff A, Arnold A, Harvey J. Management of spontaneous pneumothorax: British Thoracic Society Pleural Disease Guideline 2010. *Thorax.* 2010; 65 Suppl 2: ii18-i31. doi: [10.1136/thx.2010.136986](https://doi.org/10.1136/thx.2010.136986)
26. England GJ, Hill RC, Timberlake GA, et al. Resolution of experimental pneumothorax in rabbits by graded oxygen therapy. *J Trauma.* 1998; 45: 333-334.
27. Northfield TC. Oxygen therapy for spontaneous pneumothorax. *Br Med J.* 1971; 4: 86-88.
28. Brims FJH, Maskell NA. Ambulatory treatment in the management of pneumothorax: a systematic review of the literature. *Thorax.* 2013; 68: 664-669. doi: [10.1136/thoraxjnl-2012-202875](https://doi.org/10.1136/thoraxjnl-2012-202875)
29. Massongo M, Leroy S, Scherpereel A, et al. Outpatient management of primary spontaneous pneumothorax: A prospective study. *Eur Respir J.* 2014; 43: 582-590. doi: [10.1183/09031936.00179112](https://doi.org/10.1183/09031936.00179112)
30. Wakai A, O'Sullivan RG, McCabe G. Simple aspiration versus intercostal tube drainage for primary spontaneous pneumothorax in adults. *Cochrane Database Syst Rev.* 2007: CD004479. doi: [10.1002/14651858.CD004479](https://doi.org/10.1002/14651858.CD004479)
31. Ayed AK, Chandrasekaran C, Sukumar M. Aspiration versus tube drainage in primary spontaneous pneumothorax: a randomised study. *Eur Respir J.* 2006; 27: 477-482. doi: [10.1183/09031936.06.00091505](https://doi.org/10.1183/09031936.06.00091505)
32. Devanand A, Koh MS, Ong TH, et al. Simple aspiration versus chest-tube insertion in the management of primary spontaneous pneumothorax: a systematic review. *Respir Med.* 2004; 98: 579-590.
33. Soulsby T. British Thoracic Society guidelines for the management of spontaneous pneumothorax: do we comply with them and do they work? *J Accid Emerg Med.* 1998; 15: 317-321.

34. Chan SSW. The role of simple aspiration in the management of primary spontaneous pneumothorax. *J Emerg Med.* 2008; 34(2): 131-138. doi: [10.1016/j.jemermed.2007.05.040](https://doi.org/10.1016/j.jemermed.2007.05.040)
35. Andrivet P, Djedaini K, Teboul JL, Brochard L, Dreyfuss D. Spontaneous pneumothorax: Comparison of thoracic drainage vs immediate or delayed needle aspiration. *Chest.* 1995; 108: 335-340.
36. Harvey J, Prescott RJ. Simple aspiration versus intercostal tube drainage for spontaneous pneumothorax in patients with normal lungs. *British Thoracic Society Research Committee.* 1994; 309: 1338-1339.
37. Aguinagalde B, Zabaleta J, Fuentes M, et al. Percutaneous aspiration versus tube drainage for spontaneous pneumothorax: systematic review and meta-analysis. *Eur J Cardio-Thoracic Surg.* 2010; 37(5): 1129-1135. doi: [10.1016/j.ejcts.2009.12.008](https://doi.org/10.1016/j.ejcts.2009.12.008)
38. Baumann MH, Strange C, Heffner JE, et al. Management of spontaneous pneumothorax: an American college of chest physicians delphi consensus statement. *Chest.* 2001; 119(2): 590-602. doi: [10.1378/chest.119.2.590](https://doi.org/10.1378/chest.119.2.590)
39. Advanced Trauma Life Support. 9<sup>th</sup> ed. Chicago: American College of Surgeons; 2012.
40. Olgac G, Aydogmus U, Mulazimoglu L, Kutlu CA. Antibiotics are not needed during tube thoracostomy for spontaneous pneumothorax: an observational case study. *J Cardiothorac Surg.* 2006; 1: 43.
41. Henry M, Arnold T, Harvey J. BTS guidelines for the management of spontaneous pneumothorax. *Thorax.* 2003; 58(Suppl 2): ii39-ii52. doi: [10.1136/thorax.58.suppl\\_2.ii39](https://doi.org/10.1136/thorax.58.suppl_2.ii39)
42. Sun J, Xu Z. The role of prophylactic antibiotics in thoracostomy. *ANZ J Surg.* 2010; 80(3): 127-128. doi: [10.1111/j.1445-2197.2010.05218.x](https://doi.org/10.1111/j.1445-2197.2010.05218.x)
43. Luchette FA, Barrie PS, Oswanski MF, et al. Practice Management Guidelines for Prophylactic Antibiotic Use in Tube Thoracostomy for Traumatic Hemopneumothorax: the EAST Practice Management Guidelines Work Group. Eastern Association for Trauma. *J Trauma* 2000; 48: 753-757.
44. Parlak M, Uil SM, Van Den Berg JWK. A prospective, randomised trial of pneumothorax therapy: Manual aspiration versus conventional chest tube drainage. *Respir Med.* 2012; 106(11): 1600-1605. doi: [10.1016/j.rmed.2012.08.005](https://doi.org/10.1016/j.rmed.2012.08.005)
45. Brown SG a, Ball EL, Macdonald SPJ, Wright C, Mcd Taylor D. Spontaneous pneumothorax; a multicentre retrospective analysis of emergency treatment, complications and outcomes. *Intern Med J.* 2014 ; 44(5): 450-457. doi: [10.1111/imj.12398](https://doi.org/10.1111/imj.12398)
46. Ho KK, Ong MEH, Koh MS, Wong E, Raghuram J. A randomized controlled trial comparing minichest tube and needle aspiration in outpatient management of primary spontaneous pneumothorax. *Am J Emerg Med.* 2011; 29(9): 1152-1157. doi: [10.1016/j.ajem.2010.05.017](https://doi.org/10.1016/j.ajem.2010.05.017)