World Journal of Research and Review (WJRR)
ISSN:2455-3956, Volume-4, Issue-4, April 2017 Pages 61-64

Ultrasound Detection of Pneumothorax

Atanas Dimitrov Hilendarov, Antonia Ivanova Nedeva, Kichka Georgieva Velkova

Abstract— Introduction Lung sonography has rapidly emerged as a reliable technique in the evaluation of various thoracic diseases. Accurate diagnosis of a pneumothorax in the management of a critical patient can prevent the life-threatening situation. The aim. This article offers our experience of the use of thoracic ultrasound in the diagnosis of a pneumothorax, reviews the proper techniques used, and highlights its clinical utility. Materials and Methods The study study was carried out between June 2015 and September 2016 year. Lung sonography was performed on 110 patients -89 at the Emergency Department and 21 at the betside due to unstability of the patient. The probe is placed in a sagittal position on the anterior chest wall at about the second intercostal space, in the mid-clavicular line. During ultrasonography, the patient is sitting with arms elevated and the hand positioned behind the neck. A 3.5 MHz linear array transducer is used in all the cases and in some cases a straight linear array high frequency probe (5–13 MHz).Results Sixty-five/71.5%/ of all 110 patients, witch can be divided into two broad categories: traumatic in 59 cases (including iatrogenic) or 6 atraumatic, are with sonographic signs of pneumothorax. The patients with confirmed pneumothorax are presented with one or more ultrasound signs- in 45 patients -absence of lung sliding, in 32 - 'barcode' often called the 'stratosphere sign', in 13- loss of 'comet-tail artifacts', in 34- 'A-lines', 14 with 'lung-point sign', and in 54 the 'power slide' with loss of 'lung pulse'. 35 of the patients are treated by VATS complete pleurectomy and 5 patients submitted to VATS pleural abrasion. Conclusions Thoracic sonography for the detection of pneumothorax has become a well-established modality in the acute care setting. It is indispensible in the blunt or penetrating chest trauma patient, where the identification of a pneumothorax can prevent life-threatening consequences.

***Index Terms*—Emergency Medicine, Pneumothorax, Diagnosis, Thoracic Ultrasonography**

I. Introduction

Ultrasound has a higher sensitivity than the traditional upright anteroposterior chest radiography (CR) for the detection of a pneumothorax. Small occult pneumothoraces may be missed on CR during a trauma scenario, and CR may not always be posible in critically ill patients. The first reported use of ultrasound to detect pneumothorax in humans was by Wernecke et al., in 1987.[1] Computed tomography is a gold standard for the detection of pneumothorax, requires patients to be transported and compromising their hemodynamic stability and delaying the diagnosis.

The Focused Assessment with Sonography in Trauma (FAST) examination has now been modified to include lung imaging as part of the evaluation in a trauma patient.

Atanas Dimitrov Hilendarov PhD–Department of Diagnostic Imaging, Medical University – Plovdiv 4000, Bulgaria
Antonia Ivanova Nedeva ,MD-Department of Diagnostic Imaging, Medical University – Plovdiv 4000, Bulgaria
Kichka Georgieva Velkova MD– Department of Diagnostic Imaging, Medical University – Plovdiv 4000, Bulgaria

II. AIM

Lung sonography has rapidly emerged as a reliable technique in the evaluation of various thoracic diseases. Accurate diagnosis of a pneumothorax in the management of a critical patient can prevent the life-threatening situation. The bedside sonographic diagnosis of pneumothorax can be performed with most ultrasound machines. Most machines are now portable and can be brought to the bedside, which is especially helpful in the critically ill unstable patients.

This article offers our experience of the use of thoracic ultrasound in the diagnosis of a pneumothorax, reviews the proper techniques used, and highlights its clinical utility.

III. METHODS AND MATERIALS

A 3.5 MHz linear array transducer was used in all the cases and in some cases a straight linear array high frequency probe (5–13 MHz). [2] In some patients with cardardiac problem were used the phased array probe, generally used (2–8 MHz), as its flat and smaller footprint is better suited for imaging in between the ribs. The probe should be placed in a sagittal position on the anterior chest wall at about the second intercostal space, in the mid-clavicular line. During ultrasonography, the patient was sitting with arms elevated and the hand positioned behind the neck. Wene 35 patients was treated by VATS complete pleurectomy or pleural abrasion, patients are scanned in a supine or near-to-supine position. The probe was positioned in the intercostal space at 9 different predefined points, 2 on the hemiclavicular line (II and IV intercostal space), 3 on the midaxillary line (II, IV and VI intercostal space) and 4 posteriorly on the midline between the spine and the scapula (II, V, VII and IX intercostal space). Methods. A pneumothorax contains air and no fluid, and therefore, will rise to the least dependent area of the chest. In a supine patient this area corresponds to the anterior region of the chest at approximately the second to fourth intercostal spaces in the mid-clavicular line. This location will identify the majority of significant pneumothoraces in the supine patient, which makes it the recommended initial area for investigation in a trauma.[2,3] In contrast, air will accumulate in an apicolateral location in an upright patient.[4]

Based on the above, patients are scanned in a supine or near-to-supine position. The probe should be placed in a sagittal position (indicator pointing cephalad) on the anterior chest wall at about the second intercostal space, in the mid-clavicular line [Figure 1].

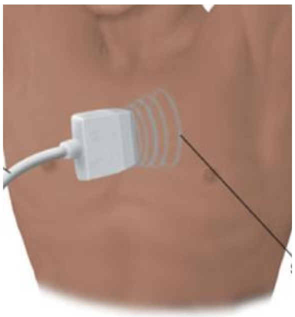


Figure 1. The probe is placed on the anterior chest wall in a sagittal orientation, at approximately the second intercostal space in the mid-clavicular line **...**

We first identifying the landmarks of two ribs with posterior shadowing behind them. This is typically called 'the bat sign'. [5] If the ribs are not visualized the probe should be slowly moved in a caudal direction (inferiorly) until two ribs appear on the screen. It is in between these two rib landmarks that the two layers of pleura, parietal and visceral, are seen sliding across one another. Lung sliding corresponds to the to-and-fro the visceral pleura on the parietal pleura that occurs with respiration. It is a dynamic sign and can be identified on ultrasound as horizontal movement along the pleural line.[6]

IV. RESULTS AND DISCUSSIONS

Forty-five/40.9%/ of all 110 patients are presented with sonographic signs of normal lung. In 35 /77.77%/ of these patients the motionless portion of the chest above the pleural line creates horizontal 'waves,' and the sliding below the pleural line creates a granular pattern, the 'sand' [Figure 2]. The resultant picture is one that resembles waves crashing in onto the sand and is therefore called the 'seashore sign'.[7,8,9]

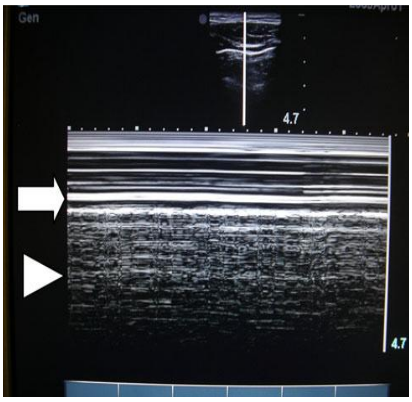


Figure 2. Normal lung on M-mode scan:the pleural line (arrow) is an hyperechoic line on top of the screen. The subcutaneous tissues, from top of the screen to the pleural line appear as parallel horizontal lines (sea). The lung below the pleural line moves with respirations and therefore the horizontal lines disappear (arrowhead) with motion, resembling the sand (shore). This pattern of normality has been termed ''sea-shore sign'

In 26/57,77%/ of cases with normal lung 'B-lines' or 'comet-tail artifacts' are reverberation artifacts that appear as hyperechoic vertical lines that extend from the pleura to the edge of the screen without fading [Figure 3]. 'Comet-tail artifacts' move synchronously with lung sliding and respiratory movements.

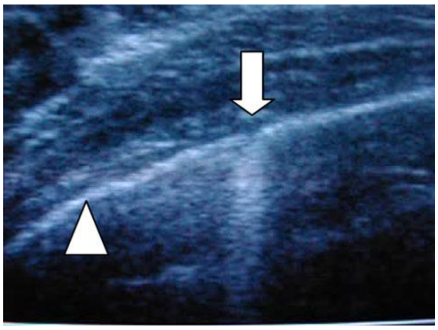


Figure 3. 'B-lines' or 'comet-tail artifacts' - the bright white hyperechoic pleural line, extending vertically to the edge of the screen.

The average time to perform this examination from experienced radiologist varies from two to three minutes; less than one minute to rule out a pneumothorax and several minutes to rule it in. Sixty-five/59.09%/ of all 110 patients are presented with sonographic signs of pneumothorax witch can be divided into two broad categories: traumatic in 59(including iatrogenic) or atraumatic in 6 of them.

In patients with confirmed pneumothorax one or more ultrasound signs occured. In 45/69.23%/ of patients -absence of lung sliding and in 32/49.23%/ with 'barcode' often called the 'stratosphere sign' are presented. In pneumothorax, there is air present that separates the visceral and parietal pleura and prevents visualization of the visceral pleura. In this situation, lung sliding is absent. Two ribs should be identified with the pleural line in between them. The typical to-and-fro movement or shimmering of the pleural line will not be present. The resultant M-mode tracing in a pneumothorax will only display one pattern of parallel horizontal lines above and below the pleural line, exemplifying the lack of movement. This pattern resembles a 'barcode' and is often called the 'stratosphere sign' [Figure 4].[8,9]

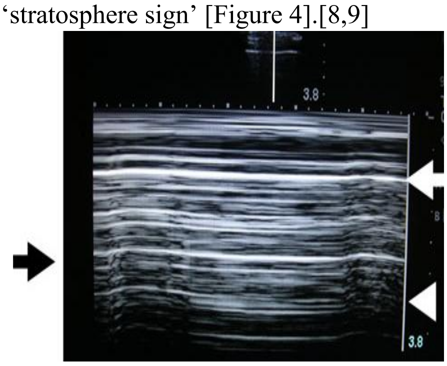


Figure 4. Pneumothorax: the pleural line (white arrow) is an hyperechoic line on top of the screen. The ''stratosphere sign'' (white arrowhead) on M-mode is due to the absence of parenchymal lung movements and is shown as parallel horizontal lines. An A line is shown (black arrow): it is a thick hyperechoic line below and parallel to the pleural line

The negative predictive value for lung sliding is reported as 99.2–100%, indicating that the presence of sliding effectively rules out a pneumothorax.[10,11,12] However, the absence of lung sliding does not necessarily indicate that a pneumothorax is present. Lung sliding is abolished in a variety of conditions other than pneumothorax, including acute respiratory distress syndrome (ARDS), pulmonary fibrosis, large consolidations, pleural adhesions, atelectasis, right mainstem intubation, and phrenic nerve paralysis.[13,14,15] Although the absence of lung sliding is not specific for pneumothorax, the combination of this with other signs improves the accuracy of the diagnosis.In 13/20%/ of patients ultrasound demonstrates the loss of ‘comet-tail artifacts’. These reverberation artifacts are lost due to air accumulating within the pleural space, which hinders the propagation of sound waves[16] In addition, ‘comet-tail’ artifacts are generated by the visceral pleura, which is not visualized in a pneumothorax, therefore, these artifacts are not generated.[12] The negative predictive value for this artifact is high, reported at 98–100%, such that visualization of even one comet-tail essentially rules out the diagnosis of a pneumothorax.[13,16,17]

‘A-lines’ are presented in 34/52.30%/ of cases -other important thoracic artifacts that can help in the diagnosis of a pneumothorax. These are also reverberation artifacts appearing as equally spaced repetitive horizontal hyperechoic lines reflecting off of the pleura ‘A-lines’ will be present in a patient with a pneumothorax. If lung sliding is absent with the presence of ‘A-lines’, the sensitivity and specificity for an occult pneumothorax is as high as 95 and 94%, respectively.[12] The ‘lung-point sign’ occurs at 14/21.53%/of patients. It is due to sliding lung intermittently coming into contact with the chest wall during inspiration and is helpful in determining the actual size of the pneumothorax. This sign can further be delineated using M-mode where alternating ‘seashore’ and ‘stratosphere’ patterns are depicted over time [Figure 5]. The ‘lung-point sign’ is 100% specific for pneumothorax and defines its border.[13,18] The more lateral or posterior the ‘lung-point sign’ is identified, the larger the pneumothorax.

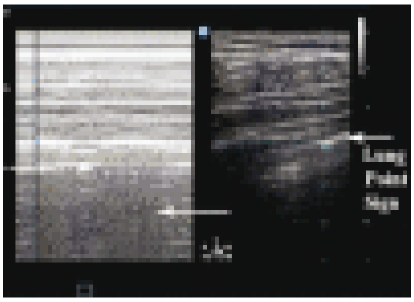


Figure 5. ‘Lung point sign.’ (Right) B-mode depicting the lung point: Sliding lung touching the chest wall. (Left) The ‘seashore sign’ (white arrow)

Studies have shown concordance between pneumothorax size on ultrasound and CT scan, reportedly within 1.9–2.3 cm.[15,20] The determination of the size of a pneumothorax is important for clinical decision-making, as larger pneumothoraces are more likely to require thoracostomy.[10,12] The ‘Power Slide’ presented in 54/49.09%/ of patients refers to the use of power Doppler to help identify lung sliding. Power Doppler is very sensitive and picks up subtle flow and movement. If there is lung sliding present, power Doppler will light up the sliding pleural line with color flow [Figure 6]. This technique can be helpful in cases of subtle sliding when direct visualization may be difficult. [21]

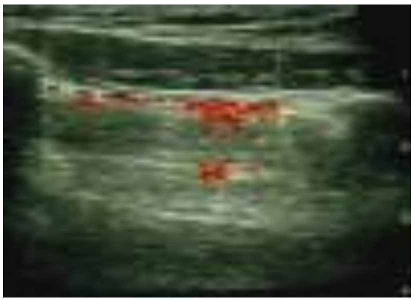
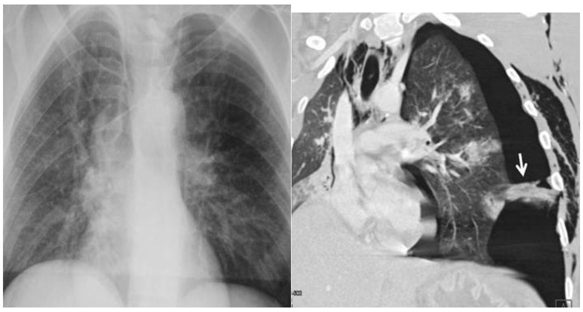


Figure 6. ‘Power slide’ in normal sliding lung. Power Doppler is used at the pleural line, which is visualized lighting up with color flow as subtle sliding is detected

The ‘lung pulse’ refers to the rhythmic movement of the pleura in synchrony with the cardiac rhythm. It is best viewed in areas of the lung adjacent to the heart, at the pleural line. The ‘lung pulse’ is a result of cardiac vibrations being transmitted to the lung pleura in poorly aerated lung. In normal well-aerated lung, the ‘lung pulse’ is not present, as lung sliding becomes dominant and resistant to cardiac vibrations.[13] In 98/89.09%/ of the patients CT examination are performed due to confirm or exclude pneumothorax. On CT it is manifested as a collection of gas in the pleural cavity accumulating behind the ventral thoracic wall. In chest Xray examinations performed in the supine position, it is often manifested very discretely, and in 30–55 % of cases it cannot be seen at all.[Figure 7]



a/ b/

Figure 7. a/ Chest radiograph reveals slightly increased transparency of the left lung and thin linear translucency contouring the left border of the lower mediastinum. b/Increased volume of the left hemithorax, multiple lung contusions, and capture of the lung parenchyma among the fragments of the ribs (arrow).

In 12 patients (10.09%), complications were observed - partial pneumothorax and local haemorrhage due to percutaneous aspiration of small pulmonary nodules (Figure 8). The higher risk of pneumothorax is seen in patients with lesions with a deep localization / biopsy path of over70mm.

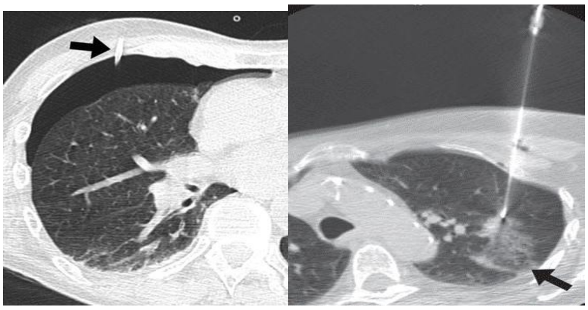


Figure 8. CT images of complications after biopsies of focal lesions – pneumothorax and restricted hemorrhage.

CT scan remains the gold standard and may still catch smaller occult pneumothoraces that ultrasound misses.

Lung sonography are performed in 110 patients -89 at the Emergency Department and 21 at the betside due to unstability of the patient. The following results are obtained: there were 64 true positive cases, 37 true negative, 5 false positive and four false negative. Overall this demonstrated that lung sonography had a sensitivity of 94.11 %, specificity of 88.09 % and accuracy of 91.81 %. The PPV(positive predictive value) is 92.75 % and the NPV(negative predictive value) – 90.24 %.

V. CONCLUSIONS

Lung sonography for the detection of pneumothorax has become a well-established modality in the acute care setting. The ease of use and portability of newer machines, combined with the improved training among physicians has allowed thoracic ultrasound to become a useful bedside tool in patients with respiratory complaints. The traditional upright AP radiograph has become less important due to its poor sensitivity in diagnosing a pneumothorax compared to ultrasound. Although CT scan remains the gold standard and may still catch smaller occult pneumothoraces that ultrasound misses, its disadvantages are becoming more apparent. In addition, ultrasound is the perfect modality in the emergency and critical care setting after performing certain procedures, such as a thoracentesis or the placement of a central line, to quickly confirm the presence of lung-sliding and to rule out an iatrogenic pneumothorax. Studies indicate that the recognition of key artifacts in thoracic ultrasound is readily teachable to both physicians as well as non-physician health care providers and its uses continue to expand in the out-of-hospital setting.[22,23]

REFERENCES

[1] Wernecke K, Galanski M, Peters PE, Hansen J. Pneumothorax: Evaluation by ultrasound-preliminary results. J Thorac Imaging. 1987;2:76–8. [PubMed]

[2] Tocino IM, Miller MH, Fairfax WR. Distribution of pneumothorax in the supine and semirecumbent critically ill adult. AJR Am J Roentgenol. 1985;144:901–5. [PubMed]

[3] Ball CG, Kirkpatrick AW, Laupland KB, Fox DL, Litvinchuk S, Dyer DM, et al. Factors related to the failure of radiographic recognition of occult posttraumatic pneumothoraces. Am J Surg. 2005;189:541–6. [PubMed]

[4] Weissberg D, Refaely Y. Pneumothorax: Experience with 1,199 patients. Chest. 2000;117:1279–85. [PubMed]

[5] Lichtenstein D, Meziere G, Biderman P, Gepner A. The ‘comet-tail artifact’: An ultrasound sign ruling out pneumothorax. Intensive Care Med. 1999;25:383–8. [PubMed]

[6] De Luca C, Valentino M, Rimondi M, Branchini M, Baleni MC, Barozzi L. Use of chest sonography in acute-care radiology. J Ultrasound. 2008;11:125–34. [PMC free article] [PubMed]

[7] Zhang M, Liu ZH, Yang JX, Gan JX, Xu SW, You XD, et al. Rapid detection of pneumothorax by ultrasonography in patients with multiple trauma. Crit Care. 2006;10:R112. [PMC free article] [PubMed]

[8] Barillari A, Kiuru S. Detection of spontaneous pneumothorax with chest ultrasound in the emergency department. Intern Emerg Med. 2010;5:253–5. [PubMed]

[9] Johnson A. Emergency department diagnosis of pneumothorax using goal-directed ultrasound. Acad Emerg Med. 2009;16:1379–80. [PubMed]

[10] Blaivas M, Lyon M, Duggal S. A prospective comparison of supine chest radiography and bedside ultrasound for the diagnosis of traumatic pneumothorax. Acad Emerg Med. 2005;12:844–9. [PubMed]

[11] Lichtenstein DA, Menu Y. A bedside ultrasound sign ruling out pneumothorax in the critically ill.Lung sliding. Chest. 1995;108:1345–8. [PubMed]

[12] Lichtenstein DA, Meziere G, Lascols N, Biderman P, Courret JP, Gepner A, et al. Ultrasound diagnosis of occult pneumothorax. Crit Care Med. 2005;33:1231–8. [PubMed]

[13] De Luca C, Valentino M, Rimondi M, Branchini M, Baleni MC, Barozzi L. Use of chest sonography in acute-care radiology. J Ultrasound. 2008;11:125–34. [PMC free article] [PubMed]

[14] Murphy M, Nagdev A, Sisson C. Lack of lung sliding on ultrasound does not always indicate a pneumothorax. Resuscitation. 2008;77:270. [PubMed]

[15] Ball CG, Kirkpatrick AW, Feliciano DV. The occult pneumothorax: What have we learned? Can J Surg. 2009;52:E173–9. [PMC free article] [PubMed]

[16] Lichtenstein D, Meziere G, Biderman P, Gepner A. The ‘comet-tail artifact’: An ultrasound sign ruling out pneumothorax. Intensive Care Med. 1999;25:383–8. [PubMed]

[17] Soldati G, Testa A, Pignataro G, Portale G, Biasucci DG, Leone A, et al. The ultrasonographic deep sulcus sign in traumatic pneumothorax. Ultrasound Med Biol. 2006;32:1157–63. [PubMed]

[18] Lichtenstein D, Meziere G, Biderman P, Gepner A. The “lung point”: An ultrasound sign specific to pneumothorax. Intensive Care Med. 2000;26:1434–40. [PubMed]

[19] Soldati G, Testa A, Sher S, Pignataro G, La Sala M, Silveri NG. Occult traumatic pneumothorax: Diagnostic accuracy of lung ultrasonography in the emergency department. Chest. 2008;133:204–11. [PubMed]

[20] Soldati G, Testa A, Sher S, Pignataro G, La Sala M, Silveri NG. Occult traumatic pneumothorax: Diagnostic accuracy of lung ultrasonography in the emergency department. Chest. 2008;133:204–11. [PubMed]

[21] Cunningham J, Kirkpatrick AW, Nicolaou S, Liu D, Hamilton DR, Lawless B, et al. Enhanced 769–71. [PubMed]

[22] Noble VE, Lamhaut L, Capp R, Bosson N, Liteplo A, Marx JS, et al. recognition of “lung sliding” with power color Doppler imaging in the diagnosis of pneumothorax. J Trauma. 2002;52:Evaluation of a thoracic ultrasound training module for the detection of pneumothorax and pulmonary edema by prehospital physician care providers. BMC Med Educ. 2009;9:3. [PMC free article] [PubMed]

[23] Monti JD, Younggren B, Blankenship R. Ultrasound detection of pneumothorax with minimally trained sonographers: A preliminary study. J Spec Oper Med. 2009;9:43–6. [PubMed]