

## My patient is short of breath: have they got a pneumothorax?

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### Abstract

Clinical diagnosis of pneumothorax in the emergency department (ED) resuscitation room can be difficult and in certain circumstances chest radiography is either impractical or the delay is unacceptable. The diagnosis must also be considered in other clinical areas such as critical care, theatres, respiratory units and acute medical units. Erect chest radiography is the standard first-line diagnostic test for pneumothorax in the ED, but the sensitivity is low (59–81%). For many patients in ED, critical care and theatre, an erect chest radiograph is not possible as the patient must remain supine. The sensitivity for a supine chest radiograph has been reported as being 45–75%. Ultrasound has been shown to be more sensitive than chest radiography in the diagnosis of pneumothorax in certain settings. This paper outlines the evidence for ultrasound in the diagnosis of pneumothorax in the point of care setting; it describes the technique and discusses the clinical application of this imaging modality.

**Keywords:** Ultrasound, scanning, diagnostic imaging, emergency medicine, anaesthesia

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### Question

In a patient who presents with shortness of breath, how can I use point-of-care ultrasound (PoCUS) to identify pneumothorax and how accurate is this diagnostic test?

### Introduction

Patients can present with pneumothorax in many clinical settings. In the emergency department (ED) patients presenting with either blunt or penetrating chest trauma are at risk of developing pneumothorax. In addition spontaneous pneumothorax is a common presentation particularly in patients with connective tissue disorders, e.g. Marfans, asthma and emphysema. The diagnosis must also be considered in other clinical areas such as critical care, theatres, respiratory units and acute medical units.

An erect chest radiograph is the standard first-line diagnostic test for pneumothorax in the ED. The sensitivity for this test has been reported as being 59–81%.<sup>1,2</sup> Computed tomography (CT) is the gold standard diagnostic test for pneumothorax. In the trauma setting it is not uncommon to pick up small anterior pneumothoraces on CT that are not visible on the trauma series supine chest radiograph. In one study 52% of patients presenting with serious head injury were found on CT to have occult

pneumothorax undetected by either clinical examination or supine chest radiograph.<sup>3</sup>

In theatres and critical care units patients requiring positive pressure ventilation are at risk of developing pneumothorax, particularly following invasive procedures such as central line placement or brachial plexus nerve block. Unrecognized pneumothorax in these circumstances can progress rapidly to tension pneumothorax with disastrous consequences.

### Case example

A 38-year-old woman presents following a fall from her horse. She is brought in by ambulance, supine with full cervical spine immobilization. She has right-sided chest and back pain. Management follows full advanced trauma life support (ATLS) protocol including extended focused assessment by sonography in trauma (FAST) scan. This is negative for haemoperitoneum, haemopericardium and haemothorax. However, a small right-sided pneumothorax is demonstrated. Trauma radiographs including a supine chest view demonstrate fractures of sixth and seventh ribs but no pneumothorax (Figures 1a and b). On completion of secondary survey an erect chest radiograph is performed and this confirms a small apical pneumothorax (Figure 2).

### Background

Wernecke *et al.*<sup>4</sup> were the first to describe the sonographic appearance of pneumothorax in humans. They described

[Supplementary videos are available online at <http://ult.rsmjournals.com/cgi/content/full/10.1258/ult.2011.011019/DC2>]

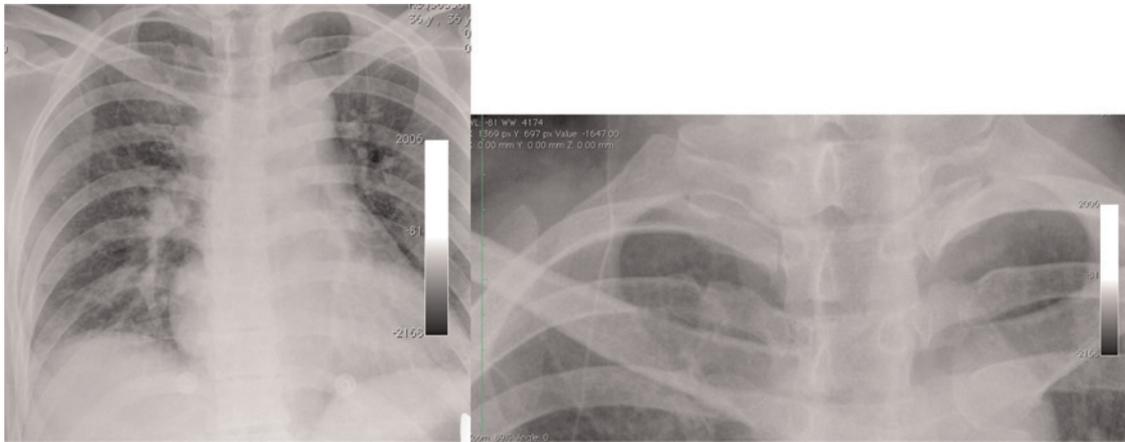


Figure 1 (a and b) Supine chest radiograph, including magnified apices

the ultrasound appearance of the visceral pleura during respiratory excursions and the comet tail artefacts seen at the boundary between the pleura and ventilated lung parenchyma. They demonstrated that these ultrasound signs were absent in patients with pneumothorax.

Targhetta *et al.*<sup>5</sup> described respiratory motions of the hyper-echoic pulmonary interface and termed this the ‘gliding sign’.

Lichtenstein and Menu<sup>6</sup> evaluated the use of ultrasonography in the diagnosis of pneumothorax in critically ill patients on the intensive care unit. They described the hyper-echoic line that lies between two ribs and represents the interface between the soft tissues of the chest wall and the aerated lung. They called this the ‘pleural line’ and noted that a to-and-fro movement synchronized with respiration could be observed in normal patients. They termed this ‘lung sliding’. When comparing ultrasound with CT in 43 patients with known pneumothorax, ‘lung sliding’ was absent in 41 (95%), present in 0 (0%) and inconclusive in two (5%). In the control group ( $n = 68$ ), the ‘lung sliding’ sign was absent in six (9%), present in 62 (91%) and

inconclusive in 0 (0%). The researchers used a 3.0 MHz cardiac transducer and evaluated in longitudinal section the anterior chest wall as far as the clavicles.

## Evidence

Since Lichtenstein and Menu<sup>6</sup> first described the ‘sliding sign’ there have been a large number of studies examining the use of ultrasound in the diagnosis of pneumothorax. Siström *et al.*<sup>7</sup> examined 27 patients and found an average sensitivity of 73%, with a specificity of 68%. This study was based on a review of video recordings of examinations performed by others, rather than realtime diagnostic ultrasound. Goodman *et al.*<sup>8</sup> examined 29 patients and found a sensitivity of 85% and a specificity of 100%. This study was based on realtime diagnostic ultrasound. Both of these studies involved patients undergoing percutaneous lung biopsy.

Rowan *et al.*<sup>9</sup> investigated 27 patients with blunt thoracic trauma, and 11 were found to have pneumothorax on CT.

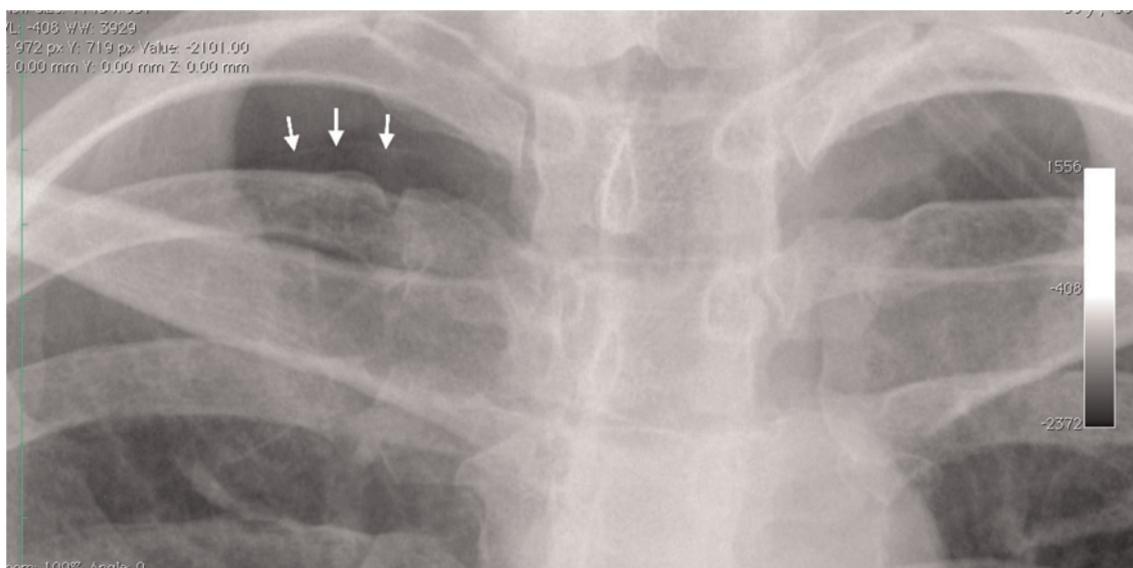


Figure 2 Erect chest radiograph. Lung edge denoted by arrows

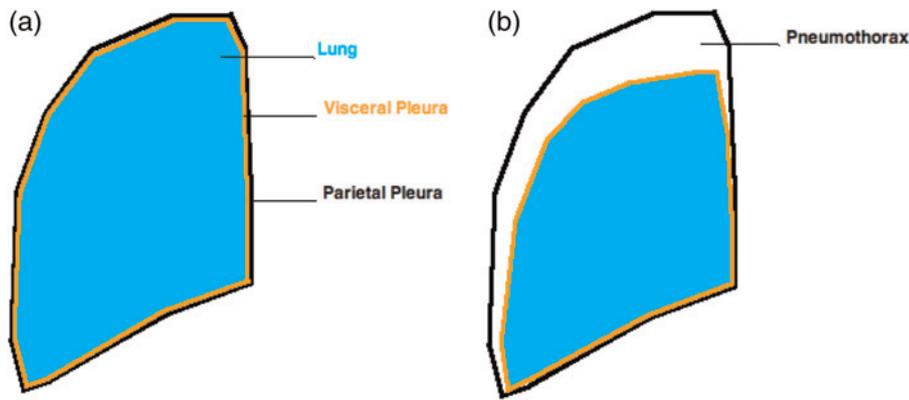


Figure 3 Line diagram of (a) normal pleural space and (b) pneumothorax

Ultrasound demonstrated all 11 pneumothoraces, whereas a supine chest radiograph demonstrated only four. They had one false-positive case, which was due to bullous emphysema. Sensitivity was therefore 100% and specificity was 94%.

In one of the largest studies to date, 328 consecutive patients were investigated.<sup>10</sup> There were 12 true positives and one false-negative. These scans were performed by trauma surgeons who had completed an ultrasound course and had been shown the technique. The sensitivity was 92.3% and specificity 99.6%.

### Anatomy and physics

The pleura is comprised of two layers; the visceral pleura which is closely applied to the lung and the parietal pleura which is closely applied to the inner surface of the chest wall, the diaphragm and the mediastinum (Figure 3a). There is a potential space between these layers called the pleural space. In the healthy lung this space is normally empty and the pleural layers are in contact with one another.

A pneumothorax is the presence of air within the pleural space (Figure 3b). This can occur as a result of trauma or spontaneously from the rupture of abnormal lung tissue, e.g. bullae.

In an erect patient the air will normally accumulate in the apex of the thoracic cavity, spreading down around the lung as it enlarges. In a supine patient the pneumothorax will accumulate anteriorly (this being the highest point of a supine patient). Quite large pneumothoraces can accumulate anteriorly without being visible on a supine chest X-ray.

Given the presence of large amounts of air, ultrasound of the chest and lung would seem to be a poor choice of imaging modality. Under normal circumstances when ultrasound meets an air interface there is almost 100% reflection of the beam, which results in no useful image formation. However, the pleura are relatively superficial and the subcutaneous tissues including pectoralis and intercostal muscles between rib spaces provide a relatively good acoustic window (Figure 4).

In normal lung there is no space between the pleural layers and so both are visible on ultrasound. Normal lung is not visualized below the visceral pleura due to beam reflection at the interface with lung parenchyma although sporadic band-like reverberation artefacts can be seen extending down the screen. These are known as B-lines or comet-tail artefacts (Figure 5). There are normally three or

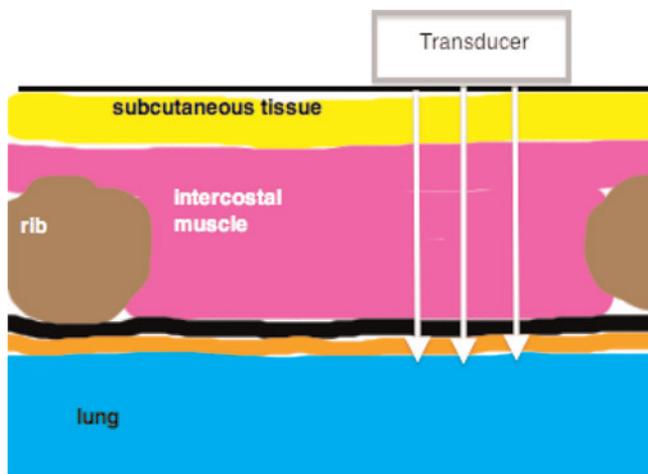


Figure 4 Diagrammatic representation of tissue layers in the chest

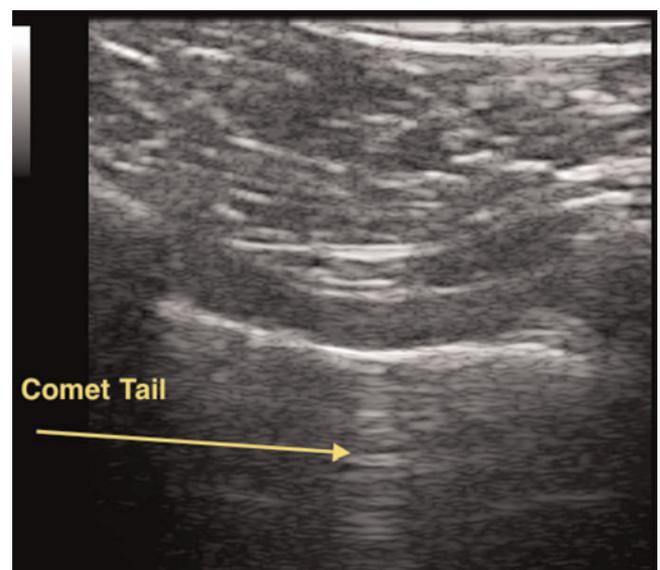


Figure 5 Comet tail artefact in a normal aerated lung

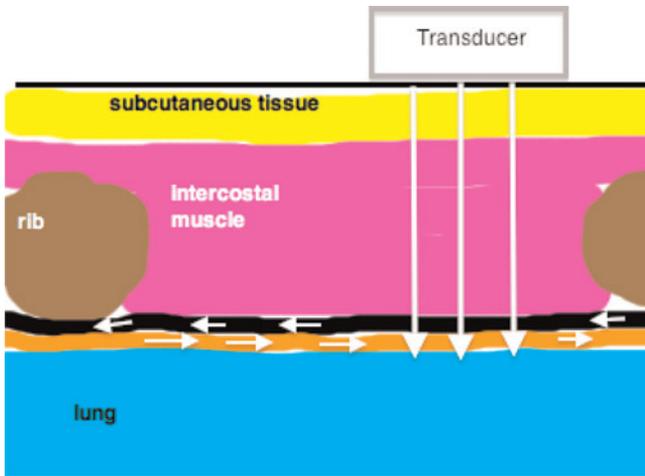


Figure 6 The ‘sliding sign’ in a normal inflated lung

four seen in the lower zones and may be absent in the upper zones. They are due to a marked difference in acoustic impedance between the pleura and aerated lung, and are more numerous in diffuse parenchymal lung disease.

During ventilation the chest wall expands and lung inflates. There is movement between parietal and visceral pleura. It is this movement of the normal lung that can be seen with ultrasound (Figure 6). The presence of air within the pleural space prevents ultrasound visualization of the visceral pleura and therefore neither the ‘sliding sign’ nor comet-tail artefacts are seen (Figure 7).

**Technique**

*Patient position:* supine.

*Transducer:* A high-frequency (6–13 MHz) linear array transducer will provide the best images although a curved array or phased array may also provide adequate images provided they are set to a high frequency.

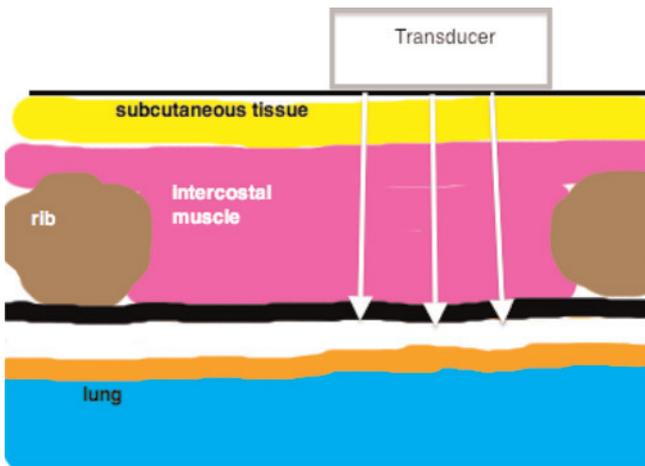


Figure 7 Absence of ‘sliding sign’ due to the air layer between the pleura in a pneumothorax



Figure 8 Surface anatomy for correct transducer placement

*Orientation:* Rotate the transducer into a longitudinal plane.

*Examination:* Place the transducer over the clavicle in the mid clavicular line and move caudally until a rib space is visualized (Figure 8). This will be seen between the two acoustic shadows of the ribs on either side, and will normally be at the second intercostal space. Alter depth to ensure the pleural line is in the centre of the screen (Figure 9). Adjust focal zone if necessary.

Observe for comet-tail artefacts (Figure 5).

Observe for ‘sliding sign’. This sign is also known as the ‘marching ants’ sign, due to its resemblance to a column of ants marching across the screen at the level of the pleura.

Switch from B-mode imaging into M-mode. Adjust the sample line so that it passes through the intercostal space.

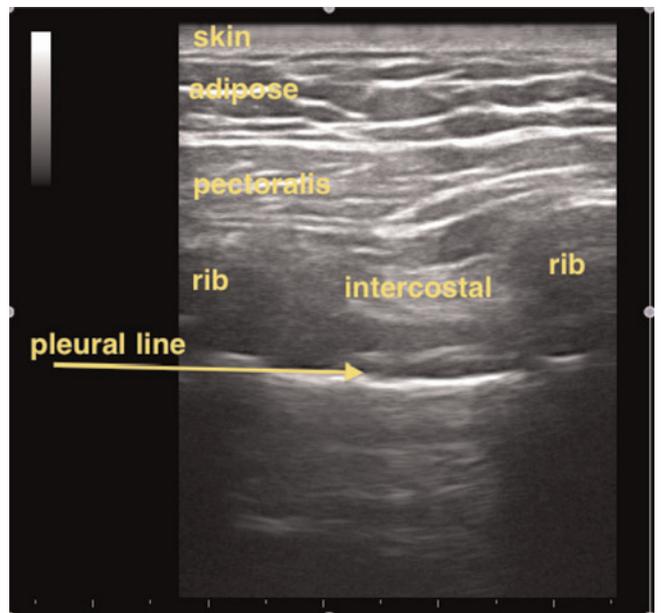
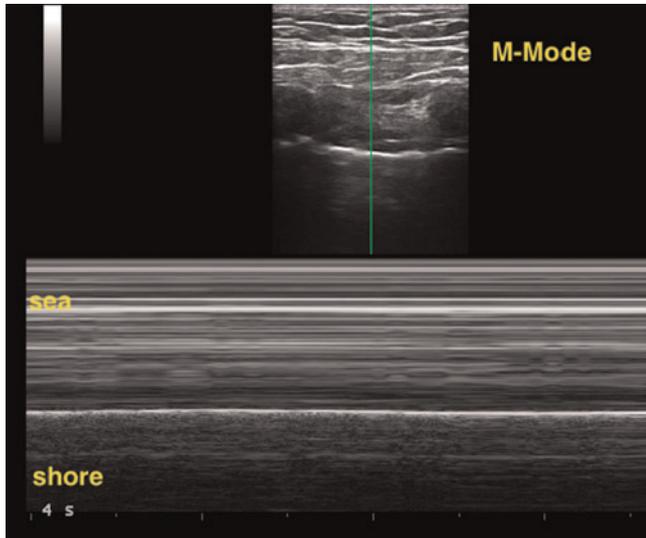


Figure 9 Anatomy demonstrated when in the correct longitudinal position



**Figure 10** 'Sea-shore' appearance in a normal lung in M-mode

Commence sampling and observe the generated image. In normal lung the M-mode image will resemble a 'sea-shore' (Figure 10). In pneumothorax the M-Mode image will resemble a barcode (Figure 11).

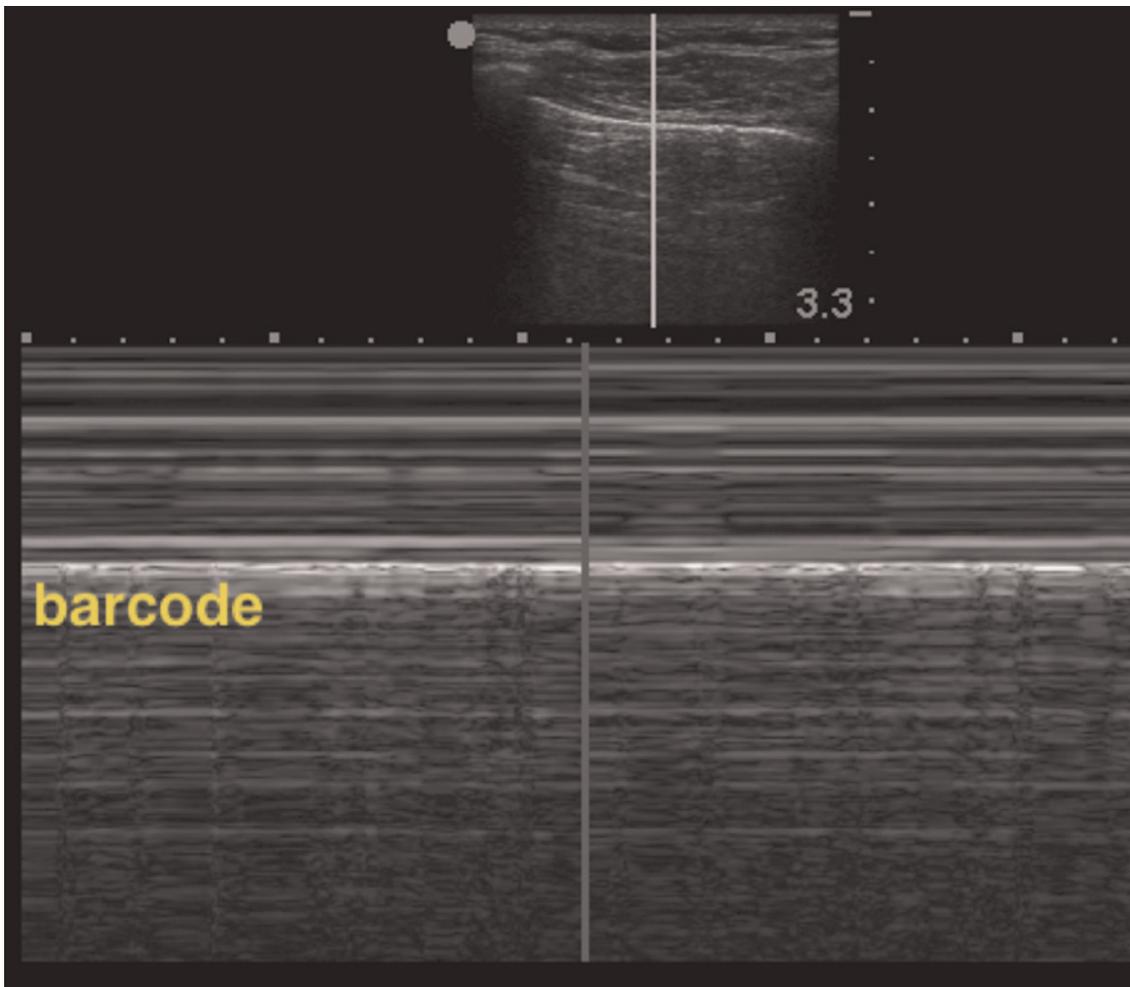
Move the transducer caudally to the next rib space. Repeat the above assessment. The transducer may have to be moved laterally on the left side to avoid the underlying heart. Continue to examine each rib space until the diaphragm is reached.

Look for the 'lung-point'. This is the point at which the lung remains in contact with the chest wall. This can be visualized with the appearance in a certain rib space of the 'sliding sign' and 'comet-tails' during inspiration. It can also be seen in M-Mode with 'sea-shore' and 'barcode' on same image (Figure 11). The 'lung-point' can be traced around the chest wall to estimate the size of the pneumothorax. The 'lung-point' sign is more specific for pneumothorax than the 'sliding sign'.

*Interpretation:* The absence of the 'sliding sign' and comet-tail artefacts strongly suggest pneumothorax. The presence of the 'lung-point sign' is diagnostic of pneumothorax.

Comet tail artefact can be absent in the upper pleural zones. The absence of 'sliding sign' can be seen in several conditions including pleural adhesions, pulmonary infiltrate/contusion, atelectasis, adult respiratory distress syndrome, and in right or left mainstem bronchus intubation.

The presence of the 'sliding sign' excludes significant pneumothorax.



**Figure 11** 'Barcode' appearance seen in the presence of a pneumothorax

## Patient management

Ultrasound can play an important role in the diagnosis and management of pneumothorax in the following settings:

### Confirmation of traumatic tension pneumothorax

Tension pneumothorax is a clinical diagnosis based on mechanism of trauma, absent breath sounds, hyper-resonance and deviated trachea. These signs can be difficult to detect in a noisy resuscitation setting. Ultrasound can be performed within a few minutes and can confirm or exclude the diagnosis allowing increased confidence in its management.<sup>11</sup>

### Diagnosis of ventilator associated tension pneumothorax

As above this is a clinical diagnosis, usually occurring in the critical care unit or operating theatre. The patients in both these settings are supine and have limited access to radiography. Ultrasound can detect the presence of pneumothorax before the clinical signs of tension have developed.

### Excluding significant pneumothorax

Ultrasound can rule out significant pneumothorax if the 'sliding sign' is seen. This can reduce the requirement for chest radiograph and CT. In an 18-month study of trauma patients in an ED, ultrasound and chest radiography were compared with CT. Chest radiography had a sensitivity of 52% and a specificity of 100%. Ultrasound had a sensitivity of 92% and a specificity of 99.4%.<sup>12</sup>

### Postaspiration of pneumothorax

Ultrasound can be used to evaluate the size of pneumothorax before and after aspiration. This can reduce the number of chest radiographs performed after attempted pneumothorax aspiration.

### Postprocedural diagnosis of pneumothorax

Ultrasound can be used at the bedside postprocedure to diagnose pneumothorax. This can be useful in a critical care setting following subclavian central line placement or intercostal nerve blocks. Sensitivity and specificity of 100% in excluding postinterventional pneumothorax was reported in a study of 53 patients following transbronchial biopsy and ultrasound guided chest tube placement.<sup>13</sup>

### Prehospital diagnosis of pneumothorax

Prehospital emergency medicine is a developing specialty. Portable ultrasound can be used to facilitate early diagnosis. Paramedics and emergency physicians are using portable ultrasound at the roadside and in ambulances to expedite early diagnosis in the trauma patient. A recent systemic review has noted the feasibility and reliability of prehospital ultrasound, but found that there was not yet enough evidence to demonstrate improved outcomes.<sup>14</sup>

## Conclusion

As shown in this case, ultrasound is more sensitive than a supine chest radiograph in the diagnosis of pneumothorax. Sensitivity for clinically significant pneumothorax is high. As a bedside test it is particularly appropriate for critical care patients, ED patients and those in the operating theatre where it can play a role in the initial management of patients with suspected pneumothorax. As with any ultrasound examination the sensitivity of this test is operator dependent; however, several studies have demonstrated encouraging sensitivity levels in the trauma population. Specificity is higher in the trauma population than the critical care population and this should be taken into account when using this test.

## DECLARATIONS

The author has no conflicts of interest to declare.

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## FURTHER READING

<http://www.youtube.com/watch?v=fntj7GLjCSU>