American Journal of Emergency Medicine 35 (2017) 1738–1742

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/ajem

Diagnostic

A novel method of assessing for lung sliding using Doppler imaging☆

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ARTICLE INFO

Article history:
Received 7 August 2017
Received in revised form 6 September 2017
Accepted 7 September 2017

Keywords:
Pneumothorax
Doppler
Lung sliding
M-mode

ABSTRACT

Ultrasound is an ideal modality in the emergency department (ED) to assess for pneumothorax given its rapid availability, portability, and repeatability to assess clinical status changes. Certain patient populations and clinical circumstances may present challenges to the performance of this examination. In this article, we review patterns of the presence or absence of lung sliding in the commonly utilized sonographic modes in the ED setting. We also describe a novel technique to evaluate lung sliding using tissue Doppler.

1. Introduction

A pneumothorax is an abnormal collection of air between the parietal and visceral layers of pleura. While computerized tomography (CT) is considered the gold standard for diagnosis, ultrasound is an ideal modality in the emergency department (ED) given its rapid availability, portability, and repeatability to assess clinical status changes. The sensitivity and specificity of ultrasound for pneumothorax are reported to be as high as 100% and 99%, respectively, in supine patients [1,2] and it has been shown to be significantly more sensitive than anterior-posterior chest radiography [1,3].

Certain patient populations and clinical circumstances may present challenges to the performance of this examination. Ultrasound waves are markedly attenuated by subcutaneous fat making it sometimes difficult to identify the pleural line in obese patients. Patients with poor pulmonary function (e.g. chronic obstructive pulmonary disease) move relatively small volumes of air or may have bullae or blebs, all of which can diminish the degree of noticeable pleural sliding. In resuscitation scenarios, regular pleural movement may be complicated by motion transmitted from cardiac activity (lung pulse) or chest compressions. In cases where pleural movement is difficult to assess in B mode, integrating additional information obtained by assessing the pleural line using other sonographic modes may assist the clinician in determining the correct diagnosis.

In this article, we review patterns of the presence or absence of lung sliding in the commonly utilized sonographic modes in the ED setting and we describe a novel technique to evaluate lung sliding using tissue Doppler, which can potentially establish the diagnosis in a single static image. The images obtained and presented here are from a patient with a CT confirmed unilateral pneumothorax.

2. General scanning technique

In the absence of pleural disease and scarring, air in the pleural cavity rises to the anterior chest wall in a supine patient, making the anterior thorax the most sensitive location for pneumothorax evaluation.

Either a low frequency (5–1 MHz) or linear array high frequency transducer (10–5 MHz) may be used to visualize the pleural interface. For each hemithorax, the probe marker is oriented cephalad and the probe is placed in the most anterior area of the thorax in the mid-clavicular line. This area will be the 2nd-3rd intercostal spaces when the patient is seated with the head of bed at 45° and in the 5th–8th intercostal spaces when the patient is supine.. The "bat wing" sign is created by the shadowing from ribs on either side of a bright white, hyperechoic line which represents the interface of the visceral and parietal pleura. (Fig. 1).

3. B Mode

When the pleural layers are in contact, the visceral pleura slides along the parietal pleura during respiration and this interface shimmers with respiration. This produces the appearance of "lung sliding". It can also been described as "ants marching on a string" [4]. This contact, and therefore the movement and sliding motion of the pleura layers, is lost when a pneumothorax is present.

☆ None of the authors have any financial disclosures.

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http://dx.doi.org/10.1016/j.ajem.2017.09.006

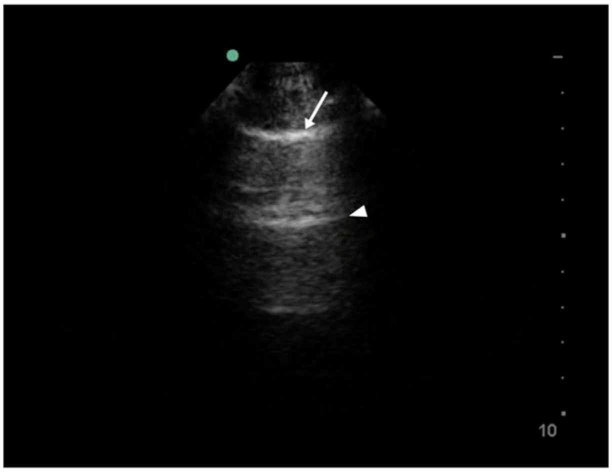

Fig. 1. Low frequency probe. "Bat wing" sign created by the posterior shadowing of ribs on either side of the pleural line (arrow). An A line is seen (arrowhead).

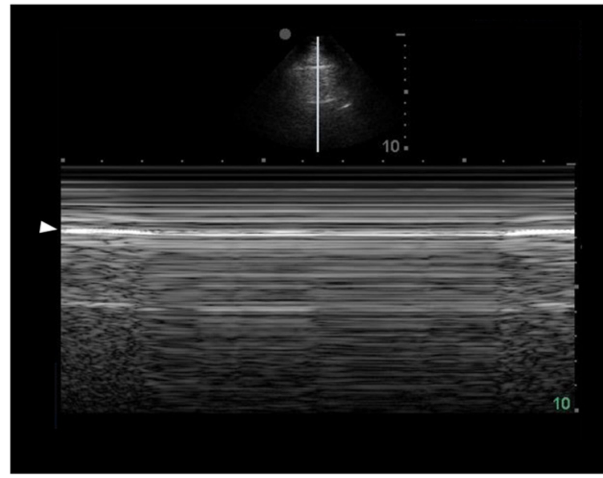

Fig. 3. Low frequency probe. Pneumothorax. M-mode image demonstrating the absence of movement (horizontal lines) below the pleural line (arrowhead).

4. M Mode

The pleural interface can also be evaluated using M-mode, which provides an image of the movement of tissue over time (x-axis = time and y-axis = tissue reflector movement). Normal lung movement will create a "seashore sign," with the stationary subcutaneous tissue at the top of the screen appearing as parallel lines, and the moving lung in the lower part of the image appearing more granular or pixelated (Fig. 2). A pneumothorax, by definition, places air between the pleura. The resultant increased impedance mismatch prevents ultrasound wave penetration beyond the layer of air in the pleural space. Absent lung sliding in B mode translates to an appearance of horizontal parallel lines across the entire M-mode image. This is known as the "barcode" or "stratosphere" sign due to its resemblance to aircraft contrails (Fig. 3).

Because it is able to document motion in a still image, an M-mode thoracic evaluation can be used to document lung sliding when video clip archiving is unavailable. A single still image of a "seashore" sign in M-mode is equivalent to a video clip to confirm lung sliding.

5. Power doppler

Power doppler is similar to other types of doppler (spectral, color) in that it detects shifts in the frequency of transmitted ultrasound waves to identify movement. Unlike color and spectral doppler, which can distinguish the direction and velocity of flow, power doppler works independently of flow direction and detects motion with greater sensitivity at the expense of directional and velocity information.

The power doppler setting is activated and the interrogation box is centered on the pleural line. The gain setting may be adjusted on the unaffected side. Starting at a low gain setting, it is gradually increased until movement is detected below the pleural interface, excluding a pneumothorax. (Fig. 4) Without changing the gain setting, the affected side is then evaluated. When a pneumothorax is present, there will be an absence of motion below the pleural interface. (Fig. 5).

Like M mode, a single static image demonstrating the presence or absence of movement below the pleural line can be used for documentation purposes. A pitfall to this technique is motion artifact secondary to probe movement, which may be falsely interpreted as normal lung sliding. Additionally, noise artifact created by the increased gain setting may also lead to a false conclusion of normal lung sliding [5].

6. A novel technique: tissue doppler

Similar to spectral doppler imaging, tissue doppler uses energy directed at a discrete, gated area to detect a frequency shift towards or away from the probe, but in tissue doppler, the interrogation gate is placed over tissue rather than blood flow. Therefore, we hypothesized that it could be used to detect the movement of lung tissue in the pleural

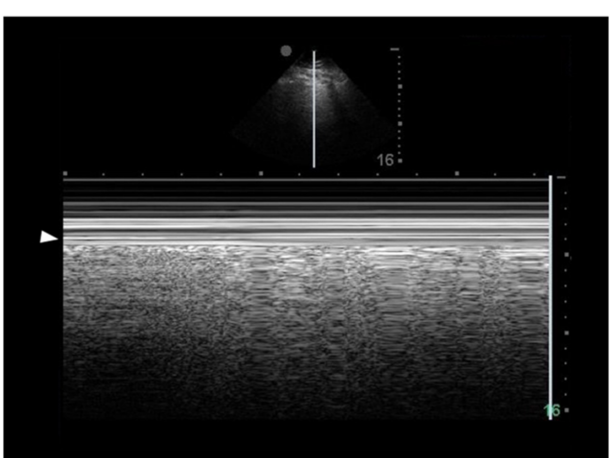

Fig. 2. Low frequency probe. Normal lung. M-mode image demonstrating movement (granular appearance) below the pleural line (arrowhead).

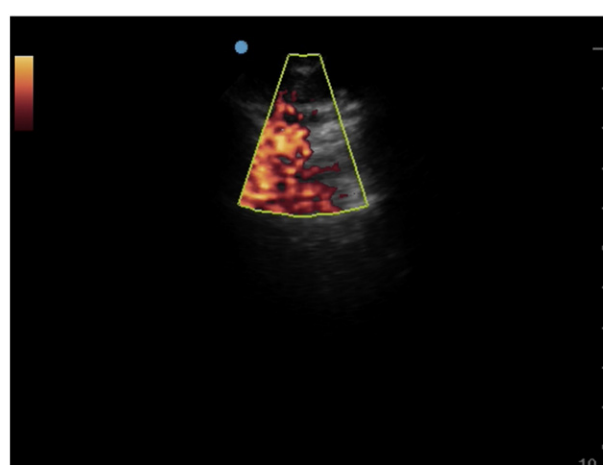

Fig. 4. Low frequency probe. Normal lung. Power doppler image demonstrating doppler flow below the pleural line.