The Journal of Emergency Medicine, Vol. ■, No. ■, pp. 1–7, 2017

0736-4679/$ - see front matter

ELSEVIER

http://dx.doi.org/10.1016/j.jemermed.2017.01.054

Ultrasound in Emergency Medicine

AIR AND ITS SONOGRAPHIC APPEARANCE: UNDERSTANDING THE ARTIFACTS

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☐ **Abstract—Background: Although air has traditionally been considered a barrier to sonographic imaging, when encountered in unusual settings it can serve as an important indicator of various pathologic states as well. Clinician recognition and thorough understanding of the characteristic pattern of artifacts generated by air are critical for making a number of important diagnoses. Case Series: We present five emergency department cases in which air was visualized in a pathologic location. Pneumothorax, pneumoperitoneum, necrotizing fasciitis, or Fournier's gangrene, and subcutaneous emphysema and pneumomediastinum, can be rapidly and easily identified on ultrasound by the presence of air artifacts. The relevant sonographic findings are described and discussed in this article. Why Should an Emergency Physician Be Aware of This?: Due to its inherent impedance mismatch with other human tissues, air has a characteristic appearance on ultrasound that includes irregular hyperechoic structures, "dirty shadowing," A-lines, and decreased visualization of deeper structures. Knowledge of the sonographic appearance of air artifacts can assist the physician in making a diagnosis, selecting appropriate additional imaging, and enlisting specialist consultation. © 2017 Elsevier Inc. All rights reserved.**

☐ **Keywords—ultrasound; bedside ultrasound; sonographic artifact; air artifact; point of care ultrasound**

INTRODUCTION

While air has traditionally been considered a barrier to sonographic imaging, when encountered in unusual settings it can serve as an important indicator of various pathologic states as well. Clinician recognition and thorough understanding of the characteristic pattern of artifacts generated by air are critical for making a number of important diagnoses.

Air has extremely low acoustic impedance relative to body tissues. The extent of reflection at an interface between two sonographic media is determined by the difference in the acoustic impedance between them. This is termed *impedance mismatch*. Therefore, when ultrasound waves strike a tissue−air interface, they are mostly reflected, limiting further tissue penetration secondary to a large impedance mismatch. This is easily demonstrated by attempting to perform ultrasound without conducting gel. The significant impedance mismatch generated by the presence of air in between the probe and skin causes significant ultrasound wave reflection, resulting in decreased further penetration of the ultrasound waves and ultimately poor or nonexistent image resolution. Using gel as a medium for ultrasound wave transmission eliminates air, reduces the impedance mismatch between the more similar gel and tissue media, allows better wave penetration, and results in successful image aquisition.

When a tissue−air interface is visualized within the body, it usually has a distinct sonographic appearance, termed *dirty shadowing*. This is primarily related to air being a strong ultrasound wave reflector, which creates an irregular hyperechoic image with reverberation artifacts that form deep to the air−tissue interface. This is in contrast to the regular, hypoechoic "clean shadowing" created by ultrasound wave-absorbing structures, such as

RECEIVED: 24 May 2016; FINAL SUBMISSION RECEIVED: 20 January 2017;
ACCEPTED: 27 January 2017

bone (1). In both cases, shadowing is a result of the failure of ultrasound waves to penetrate into deeper structures and return to the probe.

While many sonographers are adept at interpreting air when it is imaged where it is expected to be encountered, such as in the trachea, lungs, and gastrointestinal tract, its presence in pathologic locations can degrade image quality, obscure underlying anatomy, and disorient even skilled sonographers. Thus, it is important for the sonographer to be familiar with the normal sonographic appearance of these structures in order to recognize normal versus pathologic states.

We present five emergency department (ED) cases in which air was visualized in a pathologic location and the knowledge of the sonographic appearance of air artifacts allowed the physician to make the diagnosis, select appropriate additional imaging, and enlist specialist consultation. Institutional Review Board approval was not obtained, however, all patients signed a written consent for the use of images for educational purposes.

CASE REPORTS

Case 1

A 71-year-old man with history of diabetes, hypertension, cerebral vascular accident with residual right-sided weakness, and on aspirin, presented to the ED with Emergency Medical Services after a mechanical fall down 20 stairs. The patient denied head trauma or loss of consciousness but complained of right shoulder and right rib pain. Initial vital signs were blood pressure 133/81 mm Hg, heart rate 74 beats/min, respiratory rate 22 breaths/min, temperature 36.6°C (98°F), and 94% oxygen saturation on room air. Physical examination revealed decreased breath sounds on the right and tenderness to palpation over the right lateral ribs. An extended focused assessment with sonography for trauma demonstrated lack of lung sliding in B-mode (Figure 1A, B) and a stratosphere sign—a laminar tissue pattern—in M-mode, consistent with pneumothorax (Figure 2A, B). This was not noted on the subsequent supine chest x-ray study. The emergency physician discussed the sonographic findings with the trauma service, who expedited computed tomography (CT) imaging; a large right-sided pneumothorax was confirmed. The patient was emergently returned to the ED for tube thoracostomy placement.

Diagnosis: Pneumothorax

A pneumothorax is an abnormal collection of air between the parietal and visceral layers of pleura. While CT scan is considered the gold standard for diagnosis, ultrasound is an ideal modality in the ED, given its rapid availability, portability, and reproducibility in assessing clinical status changes. Sensitivity and specificity are reported to be 100% and 99%, respectively (2,3).

Either a low frequency (5-1 MHz) or linear array high-frequency probe (10-5 MHz) may be used to clearly visualize the superficial pleural interface. As trauma patients are generally supine patients, pleural free air should rise to the anterior apical regions of the pleural space, making this the location with greatest sensitivity for the diagnosis of pneumothorax. For each hemithorax, the probe marker is oriented cephalad and the probe is placed in the second or third intercostal spaces in the mid-clavicular line. The "bat wing" pattern is a normal finding and is created by the posterior shadowing of ribs on either side of a bright white, hyperechoic line that represents the interface of the visceral and parietal pleura (Figure 1B). When the pleural layers are in contact, this interface shimmers with respiration as the layers slide past each other, producing an appearance described commonly as "ants marching on a string" (4).

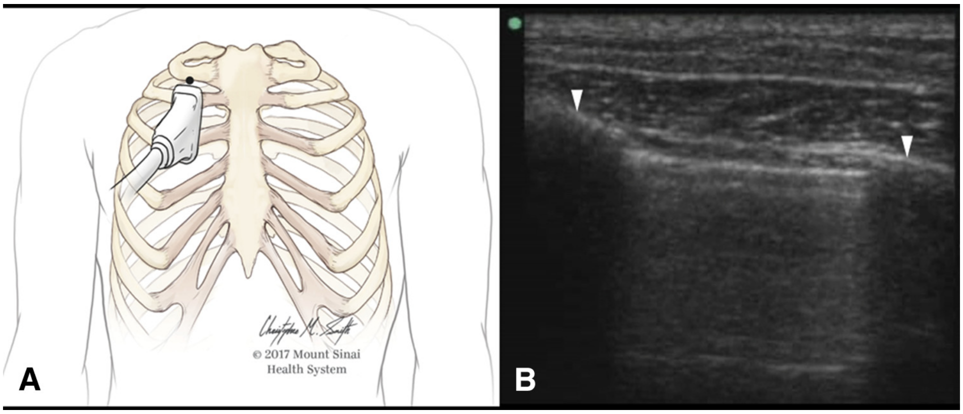

Figure 1. (A) Correct high-frequency linear probe positioning with the probe indicator oriented cephalad in the mid-clavicular line over the second intercostal space. (B) Resultant image demonstrating the "bat wing" pattern of two ribs (arrowheads) on either side of the intercostal space.