Abstract:
Point-of-care ultrasound has a wide array of applications in the emergency care of children. Over the past 3 decades, lung ultrasound has evolved and become an asset in evaluating both emergent and critically ill patients. Ultrasound of the lung was once thought to be of little utility because normal lung is aerated and ultrasound cannot directly visualize air. Thus, it was unclear how ultrasound would be beneficial. It is now evident that ultrasound of the chest is extremely useful in evaluating not only normal lung but also pathologic conditions. This article reviews the clinical utility of point-of-care transthoracic lung ultrasound in the diagnosis of pneumothorax, lung consolidations, interstitial syndromes, and pleural effusions.

Keywords:
point-of-care ultrasound; bedside ultrasound; pediatric emergency ultrasound; lung ultrasound; pneumothorax; pneumonia; pleural effusion; alveolar-interstitial syndrome

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Evaluation of Pulmonary Emergencies Using Point-Of-Care Ultrasound in the Pediatric Emergency Department: A Review

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Point-of-care ultrasound (POCUS) has a wide array of applications in the pediatric emergency department (ED). Over the past 3 decades, lung ultrasound (LUS) has evolved and become an asset in evaluating both emergent and critically ill patients. Ultrasound (US) of the lung was once thought to be of little utility because normal lung is aerated and US cannot directly visualize air. Thus, it was unclear how US would be beneficial. It is now apparent that US of the chest is extremely useful in evaluating not only normal lung but also pathologic conditions such as pneumothorax, consolidations, interstitial syndromes, and pleural effusions. The key to understanding how LUS works is rooted in US physics and artifacts, and specifically, how US waves behave when they encounter an aerated vs pathologic lung.

BACKGROUND

Point-of-care transthoracic lung ultrasound (TTLUS) was first developed and proven beneficial in adults and more recently adapted to pediatrics. In emergency and critical care settings, the role of TTLUS has traditionally been used to evaluate pleural effusions and to guide thoracocentesis.[1] However, beginning in the 1980s, there were reports that US could be used to identify patients with pneumothorax[2] as well as pneumonia.[3]

Subsequently, in the 1990s, Lichtenstein et al[4-7] began reporting their findings of bedside LUS in the intensive care unit. These initial studies identified many of the artifacts that are crucial to LUS and laid the foundation of point-of-care LUS. The term *artifact* is used to explain a by-product of US that is displayed on the screen when sound waves encounter a certain medium, but in reality is not there.

In the early 2000s, emergency physicians began publishing data on point-of-care LUS in adults in the ED. Many of the initial studies were related to pneumothorax, and by 2004, Kirkpatrick et al[8] described the evaluation of pneumothorax as part of the trauma evaluation. These data, along with other case reports and studies,[9-11] ultimately led to incorporating LUS into the focused assessment with sonography in trauma (FAST) examination, which is now termed the *extended FAST* or *EFAST*.[12] At the same time, research was underway to understand how LUS could play a part in the diagnosis and management of other disease processes. In 2005, Mathis et al[13] demonstrated its ability to diagnose pulmonary embolism, whereas Reissig and Kroegel[14] showed its utility in diagnosing and following pneumonia in 2007. Transthoracic lung ultrasound has been proven to be useful in adult disease states such as pulmonary embolism,[15-20] acute respiratory distress syndrome,[21] and acute respiratory failure.[22]

In 2012, international evidence-based recommendations for point-of-care LUS, including pediatric data, were published, reinforcing the use of POCUS for lung evaluation in children.[23] Over the past 15 years, research has been published regarding LUS in pediatrics; however, available data mainly address pneumonia and other infectious processes. There is little published research regarding LUS and the diagnosis of pneumothorax in the pediatric population. Therefore, pediatric emergency specialists have incorporated point-of-care TTLUS in the pediatric population based largely on the literature from the emergency care of adults.

This article reviews the clinical utility of point-of-care TTLUS, in pediatric emergency and critical care medicine, in the diagnosis of pneumothorax, lung consolidations, interstitial syndromes, and pleural effusions. The evidence and sonographic findings specific to each of these disease processes will be reviewed, and the future of point-of-care TTLUS in pediatrics will be discussed.

LUNG ULTRASOUND: PRINCIPLES AND TECHNIQUE

The advantage of POCUS is multifold. Bedside US can be performed concurrently with the physical examination, expanding the data available to the clinician in real-time, and is rapid and repeatable. Another major advantage is that US does not produce any ionizing radiation. In an era where efforts are made to comply with the ALARA (as low as reasonably achievable) principle regarding radiation exposure, US reduces the radiation exposure for pediatric patients.

There are a few disadvantages of which the sonographer should be cognizant. First and foremost, US is operator dependent. Therefore, clinicians must be properly trained in POCUS of the lung and deemed competent before making medical decisions based on the results. In addition, US is unable to visualize pathology below aerated lung; the disease process must extend to the pleura to be identified. Thus, any pathology lying below aerated lung will not be visualized.

The key to understanding LUS is based on physics and artifacts. In simple terms, US cannot travel through air without getting scattered and reflected; therefore, when the lung is aerated the sonographer can only visualize the ribs and the pleural surface between the ribs (Figure 1). In older children, the ribs will produce anechoic "black" shadows because the US cannot pass through bone (Figure 1). However, in younger children, the bones are cartilaginous and therefore do not produce the same shadows (Figure 2).

Below the pleura is aerated lung, which the sonographer cannot directly see. What can be seen are reflections of the pleural line, which are termed *A lines*. These A lines are horizontal lines that are a result of sound reverberating or bouncing between the pleura and the transducer; hence, the A lines are equidistant from one another (Figure 1). The pleura between the 2 ribs will give a shimmering effect because of the to-and-fro movement of the 2 layers