Case Report

Application of dynamic air bronchograms on lung ultrasound to diagnose pneumonia in undifferentiated respiratory distress

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ABSTRACT

Patients presenting with undifferentiated respiratory distress remain a diagnostic dilemma. The use of point-of-care ultrasound (POCUS) to evaluate the lungs and pleural cavities can improve diagnostic uncertainty in these patients. When visualizing consolidated lung tissue with POCUS, one may encounter static or dynamic air bronchograms. Static air bronchograms are seen in atelectasis and pneumonia, whereas dynamic air bronchograms are highly specific for pneumonia. We describe a case of a critically ill patient where bedside thoracic ultrasound helped to narrow the differential diagnosis early in the resuscitation, while standard radiographs were non-diagnostic.

1. Introduction

In recent years the use of POCUS has gained popularity for the diagnosis of pleural and parenchymal disease. Lung ultrasound (LUS) has been described to have utility in the diagnosis of pneumothorax, pneumonia, pulmonary embolism, pulmonary edema, lung contusion, pleural effusion, and most recently, COVID-19 infection [2,3]. In particular, LUS has shown promise in the diagnosis of bacterial pneumonia with several studies reporting a higher sensitivity and specificity with POCUS than chest radiograph [4,5].

2. Case

A 52-year-old female with a history of invasive ductal carcinoma of the breast and oropharyngeal dysphagia secondary to dermatomyositis which required percutaneous gastric tube placement was transported to the emergency department (ED) from an acute rehabilitation facility for dyspnea and altered mental status. She was noted to be on maintenance treatment with IVIG. Her home medications included prednisone and trimethoprim-sulfamethoxazole for PJP prophylaxis. On initial EMS evaluation, she was noted to be hypoxic to 82% and placed on non-invasive ventilation with improvement in her level of consciousness as well as her oxygen saturation, which rose to 94% at FiO₂ 70%. The remainder of her vitals revealed tachycardia to 130 beats per minute, a blood pressure of 157/103 mm Hg, a respiratory rate of 23 breaths per minute, and a rectal temperature of 37.5 °C. On questioning when the patient was more alert, she reported several days of dyspnea and cough but denied fever or chest pain. The remainder of her review of systems was negative. Physical exam was notable only for bilateral diffuse rhonchi on pulmonary auscultation.

Focused point-of-care cardiac and lung ultrasound was performed. Bedside transthoracic echocardiogram revealed mild global LV hypokinesis, a trace pericardial effusion, and >70% collapsibility of the IVC. LUS at the right lung base identified that the inferior lobe of the right lung was isoechoic to the dome of the liver with visibility of the vertebral bodies cranial to the diaphragm (known as the...
‘thoracic spine sign’). Closer inspection in this area revealed the presence of both static and dynamic air bronchograms. These findings were indicative of consolidated lung tissue and suspicious for pneumonia (Fig. 1).

Based on these ultrasound findings, a diagnosis of presumed right inferior lobe pneumonia was made. A laboratory and imaging evaluation for sepsis was initiated. Blood cultures were obtained. Arterial blood gas demonstrated pH 7.30/pCO$_2$ 55 mmHg/PaO$_2$ 72 mmHg with a lactate of 4.2 mmol/L. White blood cell count was 28,000 cells/mm$^3$, hemoglobin 12.4 gm/dL, platelets 293,000 cells/mm$^3$. The basic metabolic panel was notable for sodium 123 mmol/L, potassium 6.1 mmol/L, chloride 89 mmol/L, BUN 30 mg/dL, creatinine 0.6 mg/dL and glucose 220 mg/dL. Troponin was 180 ng/L and BNP was 148 pg/mL. She was placed on bilevel positive airway pressure for ventilatory support and treated with intravenous fluids and broad-spectrum antibiotics (vancomycin and piperacillin-tazobactam) for presumed sepsis. Repeat lactate following fluid administration trended up to 5.9 mmol/L. Her ECG showed sinus tachycardia with peaked T-waves without ischemic changes. Portable AP chest radiograph read by a board-certified radiologist demonstrated right and left lower lobe atelectasis and bilateral small pleural effusions. Given that the chest x-ray (CXR) did not confirm the presumed diagnosis, and the patient’s persistent hypoxia and tachycardia, a CT pulmonary angiogram with IV contrast was performed. While negative for pulmonary embolism, this imaging revealed diffuse centrilobular ground-glass and nodular opacities throughout the lungs, a small left pleural effusion, and bibasilar consolidation suggestive of aspiration pneumonia.

She was admitted to the medical intensive care unit for continued treatment of hyperkalemia, sepsis, and acute hypoxic respiratory failure secondary to aspiration pneumonia. The patient had a prolonged ICU course complicated by aspiration events leading to hypoxic respiratory failure and intubation, multiple failed extubation attempts, critical illness myopathy and intermittent episodes of supraventricular tachycardia. She gradually improved, was extubated and weaned to room air, and transitioned to the medical floor. Following two months of hospitalization, the patient was ultimately discharged home with home health services.

3. Discussion

While CXR remains the most common initial imaging modality of choice, it has been shown to have relatively low sensitivity for pneumonia, at about 65%, compared to CT scan as a gold standard [6]. Meanwhile, LUS has been shown to have a sensitivity of 92–98% and specificity of 93–98% [5–7]. Due to the poor performance of CXR, LUS may have utility in diagnosis of thoracic pathology, particularly in critically ill patients who may not be good candidates for transport to a CT suite for imaging, as well as for monitoring and evaluation in the critical care setting. Additionally, LUS is both easily repeatable and provides information on dynamic lung movement, an advantage compared to the static nature of CXR and CT.

Several protocols exist to guide the LUS exam, with the BLUE protocol initially described by Lichtenstein being one of the most commonly used [8]. These protocols suggest evaluation of several intercostal spaces in the bilateral anterior, lateral and posterior lung zones with high frequency linear array probes to evaluate pleural pathology and lower frequency probes such as curvilinear or phased array to evaluate lung parenchyma. Typically, healthy aerated lungs exhibit pleural sliding and an A-profile comprised of A-lines. A-lines can be described as repeating horizontal lines below the pleural line and occur due to reverberation artifacts between pleural and air interfaces [2]. B-lines are vertical lines extending from the pleura into the lung tissue, and likely represent artifacts from reverberation in areas of the lung containing interstitial edema [2,9]. Additionally, in the case of lung consolidation, it is possible to visualize hepatization of the lung, in which lung tissue appears similar in echogenicity to liver parenchyma due to either alveolar collapse or filling of alveoli with fluid [10]. The edges of these consolidated areas can create an irregular interface between aerated lung and consolidated lung. This irregular appearance has been termed ‘shred sign’ or ‘fractal sign’ [2].

Consolidated lung parenchyma may also contain air bronchograms. Air bronchograms are air-filled bronchi that become visible on ultrasound when a pathophysiologic process increases the tissue density of surrounding alveoli. Air bronchograms are identified by multiple hyperechoic densities surrounded by hypoechoic consolidated lung parenchyma. The echogenic densities are generated by

![Fig. 1. Image of right lung base using a phased array transducer in a coronal plane at the midaxillary line.](image-url)
the relatively high acoustic reflectance of the air-filled bronchi in comparison to the lower acoustic reflectance of consolidated lung tissue. Static air bronchograms remain fixed in an ultrasound clip, in contrast to dynamic air bronchograms which move with the respiratory cycle. When air bronchograms appear dynamic, it suggests that the airways supplying the lung tissue of interest are open and non-obstructed [1,11]. While both atelectasis and pneumonia may be associated with static air bronchograms, dynamic air bronchograms markedly increase the specificity for pneumonia [1]. Two prospective studies evaluating dynamic air bronchograms found that their presence had a specificity of 94% and 99% respectively for predicting pneumonia, distinguishing it from resorptive atelectasis [1,12]. In contrast, the sensitivity of dynamic air bronchograms for pneumonia evaluation is much lower at 45–61% [12]. Therefore, in the absence of dynamic air bronchograms, the clinician should evaluate for additional LUS findings to rule out the diagnosis of pneumonia. Other LUS findings associated with pneumonia include focal B-lines, ‘shred sign’ or fractal sign, and lung hepatization. For a recently published algorithmic ultrasound approach to differentiating pneumonia and atelectasis which incorporates sonographic air bronchograms and Doppler flow, see Haaksma et al. [12].

The limitations of LUS are those inherent to POCUS in general, notably the operator-dependent skill level and other patient-specific characteristics that may make ultrasound technically difficult.

Point-of-care ultrasonography is gaining popularity as a modality that may help improve diagnostic uncertainty in cases of undifferentiated respiratory distress. In addition to sparing exposure to radiation, sonography has the benefit of allowing a dynamic evaluation in all phases of respiration. It may be especially useful when CXR is nondiagnostic or the patient is critically ill.

4. Conclusion

This case exemplifies the utility of LUS in the workup of a critically ill patient presenting with undifferentiated respiratory distress. Identification of lung consolidation and differentiation between static and dynamic air bronchograms on thoracic ultrasound can assist in diagnosing pulmonary conditions. Static air bronchograms are seen in resorptive (i.e., obstructive) atelectasis or pneumonia with more proximal airway obstruction. Dynamic air bronchograms on pulmonary ultrasound suggest a consolidative pneumonia.

Declaration of competing interest

All authors declare that they have no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rmcr.2022.101706.

References

[1] D. Lichtenstein, G. Mezière, J. Seitz, The dynamic air bronchogram. A lung ultrasound sign of alveolar consolidation ruling out atelectasis, Chest 135 (6) (2009) 1421–1425, https://doi.org/10.1378/chest.08-2281.
[2] D.A. Lichtenstein, Lung ultrasound in the critically ill, Ann. Intensive Care 4 (1) (2014) 1, https://doi.org/10.1186/2110-5820-4-1.
[3] A.O. Peixoto, R.M. Costa, R. Uzun, A.M.A. Fraga, J.D. Ribeiro, F.A.L. Marson, Applicability of lung ultrasound in COVID-19 diagnosis and evaluation of the disease progression: a systematic review, Pulmonology 27 (6) (2021) 529–562, https://doi.org/10.1016/j.pulmoe.2021.02.004.
[4] A. Reissig, C. Kroegel, Sonographic diagnosis and follow-up of pneumonia: a prospective study, Respir Int Rev Thorac Dis 74 (5) (2007) 537–547, https://doi.org/10.1159/000100427.
[5] A. Reissig, R. Copetti, G. Mathis, et al., Lung ultrasound in the diagnosis and follow-up of community-acquired pneumonia: a prospective, multicenter, diagnostic accuracy study, Chest 142 (4) (2012) 965–972, https://doi.org/10.1378/chest.12-0364.
[6] F. Cortellaro, S. Colombo, D. Coen, P.G. Duca, Lung ultrasound is an accurate diagnostic tool for the diagnosis of pneumonia in the emergency department, Emerg Med J EMJ 29 (1) (2012) 19–23, https://doi.org/10.1136/emj.2010.101584.
[7] D. Orso, N. Guglielmo, R. Copetti, Lung ultrasound in diagnosing pneumonia in the emergency department: a systematic review and meta-analysis, Eur J Emerg Med Off J Eur Soc Emerg Med 25 (5) (2018) 312–321, https://doi.org/10.1097/MEJ.0000000000000517.
[8] D.A. Lichtenstein, G.A. Mezière, Relevance of lung ultrasound in the diagnosis of acute respiratory failure: the BLUE protocol, Chest 134 (1) (2008) 117–125, https://doi.org/10.1378/chest.07-2800.
[9] G. Volpicelli, M. Elbarbary, M. Blaivas, et al., International evidence-based recommendations for point-of-care lung ultrasound, Intensive Care Med. 38 (4) (2012) 577–591, https://doi.org/10.1007/s00134-012-2513-4.
[10] A. Durant, A. Nagdev, Ultrasound detection of lung hepatization, West. J. Emerg. Med. 11 (4) (2010) 322–323.
[11] L.M. Gillman, N. Panebianco, A. Alkadi, M. Blaivas, A.W. Kirkpatrick, The dynamic sonographic air bronchogram: a simple and immediate bedside diagnosis of alveolar consolidation in severe respiratory failure, J. Trauma 70 (3) (2011) 760, https://doi.org/10.1097/TA.0b013e3181ac8f82.
[12] M.E. Haaksma, J.M. Smit, M.L.A. Heldeweg, et al., Extended lung ultrasound to differentiate between pneumonia and atelectasis in critically ill patients: a diagnostic accuracy study, Crit. Care Med. 50 (5) (2022) 750–759, https://doi.org/10.1097/CCM.0000000000005303.