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E-Challenge

Pneumonia: Hiding in Plain (Film) Sight

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Herein, a case describing how point-of-care lung ultrasound was used to identify the source of progressive multiorgan failure when a chest x-ray and other routine tests failed to provide a conclusive answer is presented. The discussion after the case focuses on the following: (1) the relative strengths and weaknesses of chest x-ray versus lung ultrasound in screening for lung disease and (2) suggestions of how lung ultrasound practice can be standardized within the field of anesthesiology.

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ALTHOUGH cardiac intensivists traditionally have relied on portable chest x-rays (CXR) as the imaging modality of choice to rapidly narrow the differential diagnosis of respiratory failure, point-of-care lung ultrasound also can aid in this scenario.1 The present case describes the use of lung ultrasound to identify the source of progressive multiorgan failure when a CXR and other routine tests failed to provide a conclusive answer in a patient recovering from cardiac surgery.

Clinical Case

On postoperative day (POD) 2 after an uneventful coronary artery bypass surgery, a 68-year-old man manifested mild, but subtly worsening, multiorgan failure. Specifically, he developed increasing leukocytosis, persistent oxygen requirement, and hypotension (Supplementary Table 1). A transthoracic echocardiogram identified the following: mildly reduced left ventricular systolic function (left ventricular ejection fraction 50%); mildly reduced right ventricular systolic function; no pericardial effusion; and no other significant abnormalities. These findings were grossly unchanged from the patient’s preoperative transthoracic echocardiogram. On the same day, a portable CXR was officially read as showing “bilateral heterogeneous lung opacities” (Fig 1). Given the data available at the time, there did not appear to be an obvious unifying diagnosis to explain the patient’s three mild abnormalities. First, given the patient’s normal temperature, lack of sputum production, and the surgery having occurred 2 days prior, the CXR findings were more consistent with atelectasis than pneumonia. Second, the patient’s leukocytosis was within the range of postsurgical neutrophil demargination. Third, the mild hypotension was consistent with some combination of routine hypovolemia, mild systolic dysfunction, and/or postoperative vasoplegia. Thus, over the subsequent 24 hours, the patient’s treating providers tried multiple maneuvers to address the suspected causes of hypotension. First, the patient was given intravenous fluids (750 mL of 5% albumin in divided doses), and then his epicardial pacing rate was increased, but neither of these maneuvers resolved the hypotension. Finally, the patient was started on low-dose dopamine (3 μg/kg/min), which restored mean arterial pressure to 65 mmHg.

Despite all these interventions, the patient’s multiorgan failure generally progressed over the approximately 24 hours spanning from POD 2 to POD 3 (see Supplementary Table 1). Even though his oxygen requirement decreased somewhat, his leukocytosis and vasopressor requirement persisted and he developed new acute kidney injury. The POD 3 portable CXR (Fig 3) was officially read as showing right-sided opacities...
that “may represent atelectasis, aspiration, or infection.” The CXR findings seemed unable to explain the patient’s multigorgan failure because the findings were highly subtle, the patient’s oxygen requirement actually was decreasing, and the patient continued to have neither fever nor sputum production.

However, whereas on POD 2 the patient’s mild symptoms seemed to fall within the scope of a routine postoperative course, on POD 3 the patient’s development of acute kidney injury challenged this assumption. Because any unexplained organ failure necessitates inclusion of sepsis in the differential diagnosis and because the CXR findings in this case seemed ambiguous, the intensive care unit team decided to clarify the findings by performing point-of-care lung ultrasound. Specifically, the intensivist used a low-frequency, small-footprint probe to examine the anterior and posterior-lateral lung fields (Video 1). The findings were generally benign throughout except for a focal consolidation and small effusion in the right lung base (Fig 2, Video 2). Normally, ultrasound permits only visualization of visceral pleura, with the air content of the lung preventing visualization of lung parenchyma (Video 3). However, consolidated lung can be seen on ultrasound as tissue-like (“sonographic hepatization”) because this lung is “de-aired” in the setting of atelectasis or pneumonia.

E-Challenge

1. When encountering lung consolidation on ultrasound, what findings support a diagnosis of atelectasis versus an infiltrative process like pneumonia?

2. In what circumstances is a portable CXR superior to lung ultrasound and vice versa?

Clinical Course

In the present patient, the sonographic consolidation contained preserved lung volume and dynamic air bronchograms (see Video 2), the latter of which is pathognomonic for pneumonia. The ultrasound diagnosis compelled the initiation of antibiotics and, after a few days of therapy, the patient fully recovered. In contrast to this image, ultrasound of atelectasis
would show volume loss and absence of dynamic air bronchograms (Video 4, Fig 4).^1^3^

**Discussion**

A portable (ie, anterior-posterior) CXR uses ionizing radiation to provide a static 2-dimensional compression of a 3-dimensional space. Based on these principles, a portable CXR is better suited than ultrasound to provide certain kinds of information. First, a portable CXR allows for visualization of the entire chest in a single image, whereas ultrasound requires multiple views and will miss focal pathology in any interspace where ultrasound was not performed. Second, a portable CXR can detect pathology that lies deep to aerated lung, subcutaneous emphysema, or surgical dressings/chest tubes—any of which form an impenetrable barrier past which ultrasound waves cannot travel. Third, a portable CXR is less operator-dependent than lung ultrasound; whereas in the United States CXRs are obtained in a relatively standardized manner and interpreted by board-certified radiologists with standardized training, lung ultrasound generally is performed by providers with varying skill levels using variable image acquisition protocols.

Conversely, ultrasound has its own distinct advantages. First, an ultrasound probe’s unlimited degrees of freedom on the chest wall allows clinicians to interrogate the 3-dimensional nature of the chest cavity. This, in turn, allows ultrasound to clarify whether vague “opacities” seen on portable CXR are likely to represent intraparenchymal edema, fully consolidated lung, extraparenchymal effusion, or some combination of all these.\(^1^4\) Second, ultrasound may be more sensitive than supine CXR for detection of a small pneumothorax.\(^1\) Third, as demonstrated in the present case, ultrasound can help determine whether a lung consolidation is caused by atelectasis or an infiltrative process like pneumonia.\(^1^3\) Fourth, in the pandemic era, handheld ultrasound probes can be disinfected easily and permanently localized within severe acute respiratory syndrome coronavirus 2 wards, whereas x-ray machines must travel throughout the hospital and may be harder to fully disinfect given their larger surface area.

Because lung ultrasound is highly operator-dependent, standardizing practice is likely to enhance the clinical value of this modality. Standardization of lung ultrasound practice can, in turn, be accomplished by standardizing training and utilization protocols. Regarding training, this topic recently was evaluated by an ad hoc committee on point-of-care ultrasound of the American Society of Anesthesiologists.\(^5\) The ad hoc committee concluded that, based on the available literature, competence in lung ultrasound is likely to occur after (1) completing a didactic curriculum that covers ultrasound physics and lung sonoanatomy/pathology, (2) performing and interpreting 30 supervised lung ultrasounds, and (3) interpreting an additional 20 supervised lung ultrasounds that need not be personally performed but cover a wide spectrum of lung ultrasound pathologies. Toward this goal, the American Society of Anesthesiologists currently is developing a Certificate of Completion in Diagnostic POCUS (point-of-care ultrasound) that will include lung ultrasound as a modality.

Regarding the standardization of lung ultrasound utilization, each clinical area should develop locally appropriate
protocols. Currently, there is no universally accepted lung ultrasound imaging protocol, even within the fields of critical care and perioperative medicine. Within the authors’ department’s critical care training program, the minimum number of views is 3 per hemithorax—2 anterior and 1 posterior-lateral (see Supplementary Video 1). This approach respects the time constraints of a busy perioperative/critical care provider while still permitting detection of important pathology in anterior lung fields (eg, pneumothorax, pulmonary edema) and posterior-lateral fields (eg, pneumonia, atelectasis, and pleural effusions/hemothorax).

Notably, this approach is likely to miss focal pathology hidden behind aerated lung, such as a medially located consolidation or a posterior, loculated pneumothorax. In terms of equipment, the authors typically use a low-frequency (1-5 MHz), small-footprint probe for the entire examination—low frequency to visualize deep (ie, parenchymal) pathology and small footprint to minimize acoustic shadowing from ribs (see Supplementary Video 1). Conveniently, this probe is also the standard one used for transthoracic cardiac ultrasound. Notably, two other commonly available probes also can be used for lung ultrasound, but with some limitations. A high-frequency linear probe (typically used for vascular access) can be used if the primary goal is to screen for pneumothorax because deep penetration is not necessary to sonographically detect air between the visceral and parietal pleura. Furthermore, a low-frequency curvilinear probe (typically used for ultrasound-guided deep tissue nerve blocks and abdominal organ imaging) also can be used for lung ultrasound but at the expense of greater rib shadowing in the image.

Separate from variability in image acquisition technique, perioperative centers and intensive care units also may differ in locally appropriate indications for performing lung ultrasound based on local levels of experience with this modality and institution-specific concerns about the infectious risk of portable x-ray machines. For example, in the severe acute respiratory syndrome coronavirus 2 era, the indications for performing lung ultrasound may expand as hospitals look to minimize cross-contamination of portable x-ray equipment between patients. Currently, within the authors’ department’s critical care division, lung ultrasound typically is performed if a patient develops new/worsening respiratory insufficiency and CXR is either not rapidly available or a CXR already has been obtained but shows ambiguous findings.

In the present patient, the ambiguous findings on portable CXR combined with worsening, unexplained multiorgan failure, prompted the intensive care unit team to perform lung ultrasound. The ultrasound corroborated something that was established by the CXR—the patient did not have a large pneumothorax. More importantly, the ultrasound also clarified the “pulmonary opacities” seen on portable CXR as pneumonia, rather than atelectasis or pulmonary edema. Although a posterior-anterior/lateral CXR or computed tomography scan of the chest also could have helped to clarify the findings seen on portable CXR, these two modalities are an imperfect solution for this scenario for at least two reasons. First, both tests would have required transport of a critically ill, postcardiac surgery patient out of the intensive care unit for an off-site test, a transfer that risks dislodgement of critical hardware (eg, epicardial pacing wires) and complicates management of the patient’s hemodynamic instability. Second, because a posterior-anterior/lateral CXR and computed tomography scan are both static tests, they sometimes fail to resolve ambiguity about the nature of a consolidation. In contrast to these limitations, lung ultrasound is a portable test that is brought to the critically ill patient’s bedside and allows for visualization of the lung throughout the respiratory cycle. This increased temporal resolution allows ultrasound to capture dynamic findings—such as dynamic air bronchograms pathognomonic for pneumonia—that static tests simply cannot detect (see Supplementary Video 2).

In summary, lung ultrasound can detect many kinds of pathology visible on a portable CXR and even some conditions that are radio-occult. This could be useful to anesthesiologists not only in critical care, but also in the preoperative evaluation of pulmonary symptoms to differentiate lower versus upper respiratory infections, especially in patients who may be uniquely harmed by ionizing radiation, such as children or parutients.

Conflicts of Interest

YB has performed paid consulting for Teleflex/Arrow (Wayne, PA) in 2020 unrelated to diagnostic ultrasound.

Video 1. How to perform lung ultrasound.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1053/j.jvca.2020.07.062.

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