VIDEOS IN CLINICAL MEDICINE
SUMMARY POINTS

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Basics of Point-of-Care Lung Ultrasonography

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The following text summarizes information provided in the video.

OVERVIEW

The extensive range of diagnostic capabilities and the compact dimensions of ultrasound systems have made lung ultrasonography an indispensable tool for diagnostic imaging. Lung ultrasonography facilitates quick diagnosis at the bedside and is especially useful in emergency conditions.[1-4] We briefly review the basics of point-of-care lung ultrasonography and describe practical considerations for performing the procedure in patients with the most common causes of dyspnea.

ANATOMY OF THE LUNGS

Ultrasonography can be used to examine the tissue layers of the chest wall. The ultrasound beam travels through the administered gel and subsequently penetrates skin, subcutaneous tissue, the chest-wall muscles, the ribs, the intercostal muscles, two pleural laminae (the parietal pleura and the visceral pleura) with the pleural cavity in between them, and the lungs. Connective-tissue septa extend from the visceral pleura deep into the lung, forming delicate support for the alveoli.

FEATURES OF A NORMAL LUNG ON ULTRASONOGRAPHY

The typical view acquired during lung ultrasonography is contained between two adjacent ribs, where the pleural line can be visualized. The acoustic shadowing caused by the two adjacent ribs is called the bat sign. Healthy lungs contain a substantial amount of air that transmits ultrasound waves very poorly. Most of the air is reflected at the air–tissue boundary and is seen as horizontal artifacts called A lines. The distance between the pleural line and an underlying A line is equal to the distance between the pleura and the ultrasound transducer. Several A lines may be visible and are always at equal distances from one another. Fully aerated lungs have the following features (Fig. 1): visible lung sliding, which is movement of the pleural line in accordance with respiration; a visible smooth and echoic pleural line; and visible A lines.[3,4]

INDICATIONS AND CONTRAINDICATIONS

Point-of-care lung ultrasonography allows for the assessment of patients with acute dyspnea, which is usually associated with pneumonia, pulmonary edema, pleural effusion, or pneumothorax and may occur with chronic obstructive pulmonary disease (COPD), asthma, or pulmonary embolism.[1-4] In patients with respiratory failure, point-of-care lung ultrasonography can be used not only to determine the cause of dyspnea but also to monitor lung involvement throughout the disease course and to rule out other, overlapping emergency conditions.[5] There are no absolute contraindications to lung ultrasonography.

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N Engl J Med 2023;389:e44.
DOI: 10.1056/NEJMvcm2108203

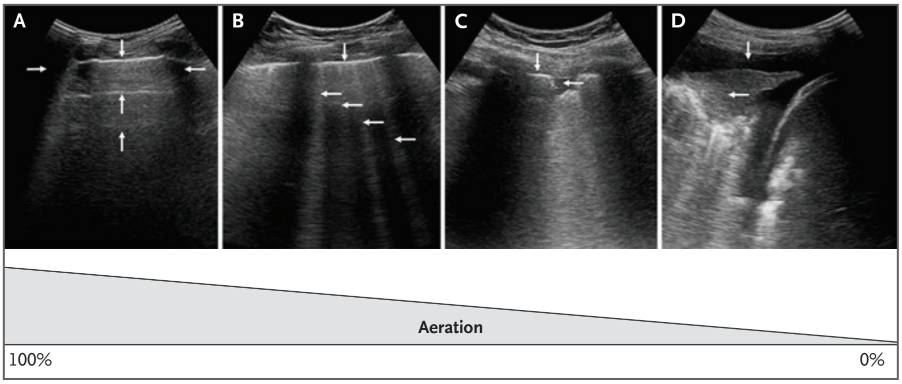

Figure 1. Ultrasound Images of the Lung According to the Level of Aeration.

A fully aerated lung (Panel A) has a smooth and hyperechoic pleural line (down arrow) and horizontal artifacts called A lines (up arrows). Acoustic shadowing from the ribs can be seen (left- and right-facing arrows). A lung with edema (Panel B) has multiple vertical artifacts called B lines (left-facing arrows) and a normal pleural line (down arrow). A lung with consolidations (Panel C) has hypoechoic structures, which are formed by collapsed and airless alveoli (left-facing arrow) that are surrounded by aerated alveoli; the consolidations move together with lung sliding, which is movement of the pleural line (down arrow) in accordance with respiration. A lung with complete loss of aeration (Panel D) has lobular consolidation (left-facing arrow) and pleural effusion (down arrow).

EQUIPMENT

The following equipment is required to perform point-of-care lung ultrasonography: an ultrasound device, a low-frequency transducer, ultrasound gel, and cleaning wipes to decontaminate the equipment after the examination. The choice of ultrasound probe depends on availability, the physician's preference, and the clinical situation. Any transducer can be used for lung ultrasonography; however, convex and microconvex transducers seem to be the most appropriate. The quality of the image obtained during lung ultrasonography may rely on the adjustment of four settings: gain, depth, focus, and mode. In the evaluation of patients with confirmed or suspected highly infectious diseases, personal protective equipment should be used in accordance with institutional procedures.

PREPARATION

Place the patient in an upright seated, semirecumbent, supine, or prone position. Select the dedicated lung preset setting on the ultrasound device. If this setting is unavailable, disable the image enhancement filters, such as cross-field imaging, noise reduction, and harmonic imaging; use of these filters may interfere with the interpretation of the findings.

Apply a small amount of ultrasound gel to the scanning surface of the transducer. Position the probe on the patient's chest wall vertically along the longitudinal axis (Fig. 2), with the probe indicator (the ridge, groove, or indentation on the probe) pointing toward the patient's head. The probe indicator corresponds to the orientation marker on the ultrasound screen, which is typically seen in the upper left corner. Minimize your hand movements so that the dynamics are generated by the patient and not by your hand.

Set the gain on the ultrasound device to zero and then adjust it so that the rib shadows are black and the pleural line is white. Avoid making the image too bright (overgaining), because it may interfere with the assessment. Set the depth to 10 cm. Depending on the patient's anatomy, you may need to increase the depth to a level of up to 16 cm. You can lower the depth to better visualize the pleura. Set the focal length at the level of the pleural line in order to attain the clearest view of this structure.[4]

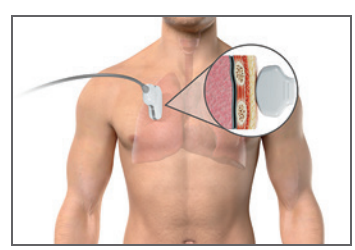

Figure 2. Placement of the Transducer during Lung Ultrasonography.

In addition to the conventional B mode, which renders a two-dimensional image, most ultrasound devices can be set to M mode, which renders a time-motion image. During lung ultrasonography, M mode is most commonly used to assess the mobility of anatomical structures, especially lung sliding.

EXAMINATION

Several examination techniques and approaches to finding the zones of the chest have been proposed to facilitate archiving of the examination, communication of the results, and monitoring of the disease course. The most common approach to zoning is the division of each hemithorax into six segments, which are limited on the front by the parasternal line and fifth intercostal space; on the lateral side by the anterior axillary line, posterior axillary line, and fifth intercostal space; and on the back by the paravertebral lines and subscapular line. The two sides of the chest wall are compared during the examination.

At the initial stage of many lung diseases, the ultrasound image may show normal findings. When lung aeration is reduced, the subpleural structures along the course of the ultrasound beam become more accessible and produce a variety of abnormal findings (Fig. 1). Interstitial edema causes thickening of the subpleural interlobular septa, which are surrounded by alveolar gas. The vertical artifacts that result from the entrance of the ultrasound beam into these structures are called B lines.

B lines are hyperechoic artifacts resembling laser beams that arise from the pleural line. They move in unison with lung sliding, reach the bottom of the screen, and erase the A lines. It is sometimes helpful to increase the depth of imaging to differentiate B lines from Z lines, which are irrelevant, short, ill-defined vertical artifacts that arise from the pleural line.

One or two B lines per field can be present in healthy lungs. The number of B lines increases with exacerbation of interstitial edema. In severe cases, multiple B lines can merge, forming a pattern called white lung. The complete loss of alveolar aeration leads to the formation of tissuelike patterns called consolidations. Subpleural consolidations are hypoechoic structures that move together with lung sliding.[3,4]

FEATURES OF THE MOST COMMON LUNG CONDITIONS ON ULTRASONOGRAPHY

Community-Acquired Pneumonia

Community-acquired pneumonia initially involves only certain lung areas and occurs asymmetrically. The following features may be observed: focal pleural-line abnormalities, multiple B lines, multifocal confluent B lines (white lung), subpleural consolidations, lobular or segmental consolidations, and air or fluid bronchogram.[1-4]

Interstitial Pneumonia

Various factors — such as viral infection, toxic exposures, and autoimmune diseases — may cause interstitial pneumonia. The following features are typically observed: focal pleural-line abnormalities, multifocal B lines that are usually bilateral, white lung, and multifocal subpleural consolidations. Of particular concern is the inhomogeneity of the lungs. Even in advanced interstitial pneumonia, the inflamed lung regions may be separated by fully aerated areas, known as spared areas. Daily patient evaluation can be helpful in assessing the effectiveness of treatment.[5]

Pulmonary Edema

Unlike pneumonia, edema typically occurs symmetrically at the lowest point of the lungs, owing to gravity. The ultrasound image shows B lines, which may increase in number until the lung region appears white (white lung). Symmetric involvement of four lower chest quadrants is pathognomonic for cardiogenic pulmonary edema. Echocardiography may be used to facilitate diagnosis.[3]

Pleural Effusion

Pleural effusion is a collection of fluid in the pleural cavity that is typically located at the lowest point of the thoracic cavity owing to gravity. Pleural effusion is best assessed by applying the probe to the base of the chest with the patient placed in a semirecumbent position. Three elements should be visualized to correctly identify the fluid location: the pleural cavity, the diaphragm, and an abdominal organ, either the liver or the spleen. Sometimes, the thoracic spine can be visualized during the examination. This nonspecific finding, known as the spine sign, indirectly indicates the presence of fluid in the pleural cavity.

Lung ultrasonography can detect as little as 20 ml of fluid, and there are numerous methods of estimating the volume of a pleural effusion. One of the most accepted techniques is to measure the distance from the diaphragm to the base of the lung and from the lateral surface of the chest wall to the lung. These measurements, obtained in centimeters, should then be added together and multiplied by 70. The resulting volume is expressed in milliliters.[6]

The curtain sign occurs when a fully aerated and expanded lung obstructs the view of the diaphragm underneath. This finding can rule out the presence of a pleural effusion when the patient is placed in an upright or semirecumbent position.

Pneumothorax

Pneumothorax can be life-threatening. The following findings are suggestive of a diagnosis of pneumothorax: the absence of lung sliding, the absence of B lines and subpleural lesions, the absence of the lung pulse, and the presence of the lung point.

Although the presence of lung sliding rules out pneumothorax in the scanned area, the absence of lung sliding is not pathognomonic for pneumothorax. Lung sliding may be absent in other conditions, including bronchial obstruction. When lung sliding is difficult to detect, it can be helpful to use a linear transducer or to perform lung ultrasonography in M mode, in which lung motion is thought to resemble the sea and sand and is sometimes called the seashore sign. In M mode, the absence of lung sliding results in a static image, known as the barcode or stratosphere sign. In addition, transmission of the heartbeat to the lungs can result in vertical artifacts that do not cross the pleural line; these artifacts are known as the lung pulse.

The only pathognomonic sign of pneumothorax is the lung point, which is defined as the point at which healthy lung starts and the pneumothorax ends. This sign occurs when the lung appears suddenly and transiently on the ultrasound image. Lung sliding can be seen on one side of the lung point, and on the other side, there is no lung sliding. The lung point and the stratosphere sign are shown in Figure 3.[1-5]

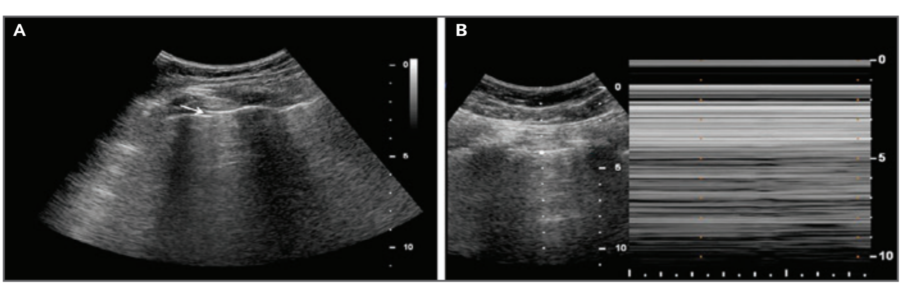

Figure 3. Ultrasound Images of the Lung with Features of Pneumothorax.

Features of pneumothorax include lung point (Panel A, arrow), which is the only pathognomonic sign, and the stratosphere sign (Panel B), which results from the absence of lung sliding on ultrasonography performed in M mode and may occur with many conditions.

COPD and Asthma

In a patient with dyspnea and normal findings on lung ultrasonography, ruling out other pathologic conditions may point the final diagnosis toward exacerbation of COPD or asthma. Obstruction can be diagnosed on ultrasonography by assessing the respiratory movements of the diaphragm in M mode. During the examination, the motion of the diaphragm can be observed as a hyperechoic line that rises during inspiration and falls during expiration. The patient should be asked to take a deep breath and then to force expiration through an open mouth. The ratio of the diaphragmatic excursion during the first second of expiration to the diaphragmatic excursion during the entire expiration is known as the M-mode index of obstruction. A value of less than 0.77 is considered to be a possible cutoff for an obstructive pattern on lung spirometry.[7]

Pulmonary Embolism

Lung ultrasonography is of limited diagnostic value in patients with pulmonary embolism, which is often a diagnosis of exclusion. If a patient with dyspnea has normal findings, additional testing may be necessary, including an evaluation for deep-vein thrombosis. If pulmonary embolism is suspected or diagnosed, computed tomographic pulmonary angiography, echocardiography, or scintigraphy may be indicated to select the treatment and assess prognosis.

Doppler imaging is an additional technique for the diagnosis of pulmonary embolism. Occasionally, there are oval, round, or wedge-shaped consolidations with visible blood flow that ends proximally. This finding, called the vascular sign, distinguishes consolidations related to pulmonary embolism from inflammatory consolidations, in which blood flow is seen within the entire consolidation.[8]

LIMITATIONS

Although lung ultrasonography can be used to establish the cause of dyspnea, it has several limitations. There is a limited capability to detect pathologic conditions that do not extend to the pleura. Diseases involving the lung hilum and early-stage bronchopneumonia are often not visible.

Different medical conditions may show overlapping or identical findings. B lines may occur in patients with other diseases, such as cardiac or noncardiogenic pulmonary edema, acute respiratory distress syndrome, or fibrosis. Consolidations can suggest infection but can also be seen in patients with pulmonary embolism. Lung ultrasonography cannot be used to determine the cause of interstitial pneumonia or the cause of bacterial superinfection because of overlapping findings.

Although lung ultrasonography has increased the possibility of detecting pneumothorax at the bedside, accurately assessing the size of the pneumothorax can be challenging with ultrasonography; locating the lung point can be time consuming and sometimes impossible. Therefore, in patients with pneumothorax, management decisions should instead be based on the clinical condition or other test results. It is important to note that the absence of lung sliding is not pathognomonic for pneumothorax and may result from other clinical conditions, such as bronchial-tree obstruction or subpleural emphysematous bullae.

The presence of subcutaneous emphysema or morbid obesity in the patient, the presence of medical devices, and the position of the patient's body may all limit access to certain areas of the chest. Subcutaneous emphysema can mimic other conditions, although the visible artifacts do not extend from the pleural line, and lung sliding is absent. Proper examination technique and identification of the ribs are needed to determine the correct location of the pleural line, thereby reducing the likelihood of misdiagnosis.

A notable limitation of lung ultrasonography may be operator inexperience. Periodic training and the use of innovative techniques, including artificial intelligence–based algorithms for artifact identification, can support the diagnostic process and reduce misinterpretation of the obtained images. Finally, a poorly cleaned ultrasound machine can be a potential source of new infections.

SUMMARY

Lung ultrasonography is a well-established, broadly accessible, and cost-effective diagnostic tool for patients with dyspnea. It may be used for diagnosis, treatment monitoring, or the detection of complications or overlapping diseases. Findings on lung ultrasonography should be interpreted within the clinical context.

Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

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