The Medicine Forum

Volume 24 Article 15

2023

A Guide to Point of Care Ultrasound Lung and IVC Examination of a Volume Overloaded Patient

Michael Dong, MD
Thomas Jefferson University, michael.dong@jefferson.edu

Frances Mae West, MD
Thomas Jefferson University, Frances.west@jefferson.edu

Jonathan Foster, MD
Thomas Jefferson University, jonathan.foster@jefferson.edu

Rebecca Davis, MD
Thomas Jefferson University, rebecca.davis@jefferson.edu

Jillian Cooper, MD
Thomas Jefferson University, jillian.cooper@jefferson.edu

A Guide to Point of Care Ultrasound Lung and IVC Examination of a Volume Overloaded Patient

Michael Dong, MD[1], Frances Mae West, MD[1,2], Jonathan Foster, MD[1], Rebecca Davis, MD[1], Jillian Cooper, MD[1]

1. Department of Internal Medicine, Thomas Jefferson University Hospital, Philadelphia, PA
2. Division of Pulmonary, Allergy, and Critical Care, Department of Medicine, Thomas Jefferson University, Philadelphia, PA

LEARNING OBJECTIVES

1. Learn the technique for lung point of care ultrasound.
2. Identify and interpret the lung ultrasound findings that would be consistent with volume overload.
3. Learn the technique for inferior vena cava (IVC) point of care ultrasound.

INTRODUCTION

A patient presents with dyspnea, hypoxia, and lower extremity edema. Their history is notable for recent high salt intake and non-compliance with diuretics, and their lungs have rales bilaterally. Clinically, we can diagnose a heart failure exacerbation with pulmonary edema. However, we often rely on X-ray and computed tomography (CT) imaging to support the clinical diagnosis and explore the etiology of the hypoxia and dyspnea to narrow the differential. Ultrasound is an effective modality for identifying pulmonary edema and pleural effusions while at the same time ruling out other etiologies such as pneumonia and pneumothorax. With bedside point of care ultrasound (POCUS), there is no radiation risk and no delay in obtaining imaging. A systematic review and meta-analysis study by Maw et al. published in 2019 found that lung ultrasound diagnosis of pulmonary edema in the setting of clinical suspicion for acute decompensated heart failure had a pooled sensitivity of 0.88 and specificity of 0.9, which is superior to X-ray imaging which demonstrated a pooled sensitivity of 0.73 and a pooled specificity of 0.9.[1]

A systematic review and meta-analysis study by Soni et al. published in 2015 found that lung ultrasound diagnosis of pleural effusions had a pooled sensitivity of 0.93 and specificity of 0.96. In comparison, the studies assessing X-ray imaging for the diagnosis of pleural effusions vary, but the sensitivity ranges from 0.33-0.94, and the specificity ranges from 0.7-1.0.[2] On posterior-anterior chest radiography, it is estimated that >200cc of fluid is needed to cause blunting of the costophrenic angle.[3] In comparison, ultrasound could detect as little as 5cc of fluid in the pleural space, and it allowed the detection of >100cc of fluid with 100% sensitivity.[4–6]

The ultrasound examination of the IVC can also be used to estimate right atrial pressure. It can be used as an objective data point for assessing volume overload in the appropriate clinical context. The 2010 guidelines for echocardiographic assessment of the right heart by Rudski et al. use an IVC diameter and collapsibility with inspiration to estimate the right heart pressure.[7] IVC diameter of 2.1cm and collapse of the IVC with inspiration are the two criteria used to estimate the right atrial pressure.

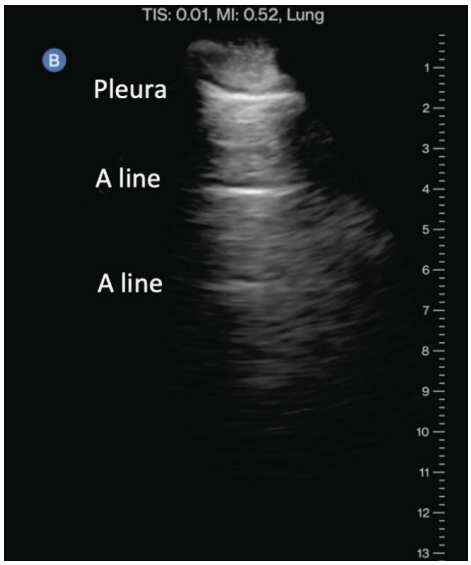
While the POCUS lung and IVC exam may not change your plan to initiate diuresis for the patient, it can help you monitor the patient's response to diuresis over their hospital course. The REVERSE Falls protocol developed by Dr. Ahmar uses the number of B lines on lung ultrasound and the diameter of the IVC in successive scans to guide diuresis management.[8]

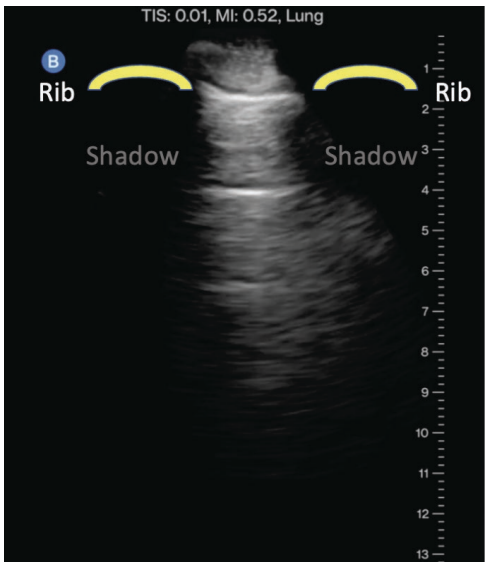
Kimura et al. in 2011 created the Cardiopulmonary Limited Ultrasound Evaluation (CLUE) protocol, which combines four views to predict if there is a reduced left heart ejection fraction. Using only the parasternal LV long-axis, subcostal IVC, and two apical lung views, the protocol assesses LV dysfunction, LA enlargement, IVC plethora, and B-lines in the lung apices. When evaluating LV ejection fraction < 40%, the CLUE protocol had a sensitivity of 69%, specificity of 91%, and accuracy of 89%.[9] It is a validated protocol that can also help in your evaluation of a volume overloaded patient.

TECHNIQUE

Lung

When performing lung ultrasonography, there should be at least 6 points of imaging: bilateral mid-clavicular 2nd intercostal, bilateral 6th intercostal anterior axillary line, and bilateral PLAPS points or pleural bases. The probe indicator should be directed caudally at all six points. The imaging windows are between rib spaces.

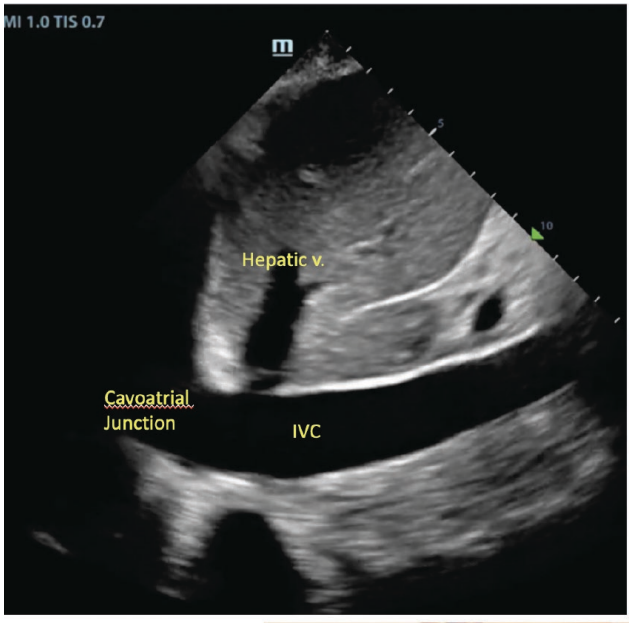


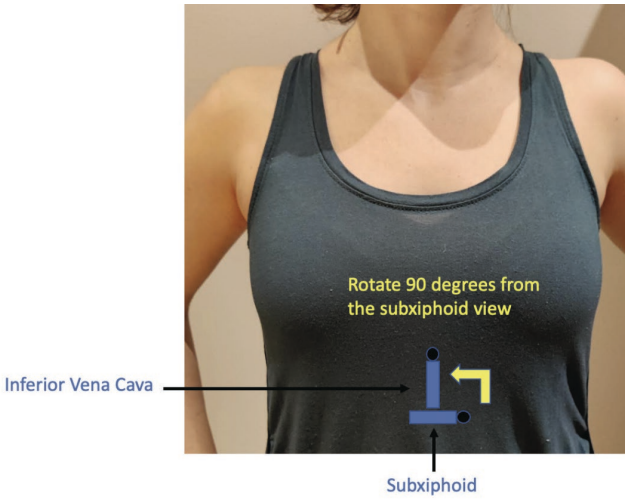


In this healthy lung parenchyma ultrasound image, A-lines are normal imaging artifacts that reflect and repeat the pleura-air interface. The top line is the pleura, where lung sliding would be seen. The black spaces flanking the lung tissue are shadows behind the ribs. Sound cannot pass through bone and thus causes acoustic shadowing.

IVC

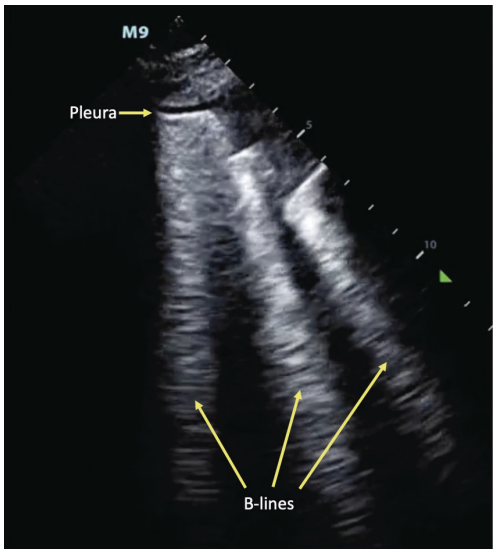
The Inferior vena cava (IVC) view is obtained by first identifying the right atrium on the subxiphoid view, then rotating the probe 90 degrees so that the probe indicator is directed caudally. Ideally, the hepatic vein should be visualized as merging with the IVC. Measurement of the IVC diameter should be 2cm from where the IVC and hepatic vein join. The patient should be asked to either "sniff" or take an inspiratory breath. While inspiring, there should be an assessment of whether the IVC diameter decreased by > 50%.





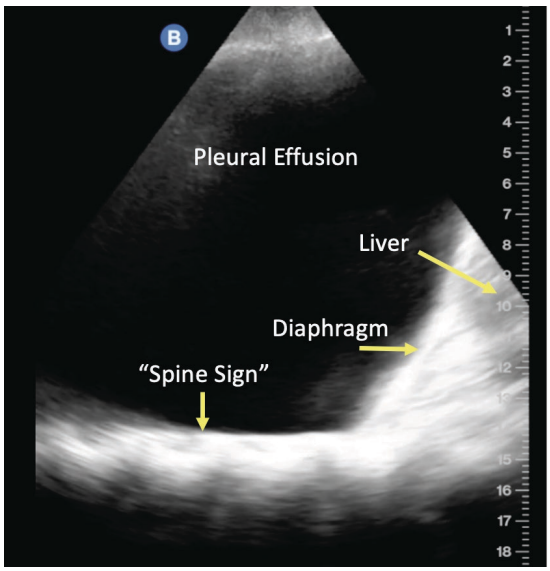
Findings Consistent with Volume Overload

1. Bilateral and diffuse B lines



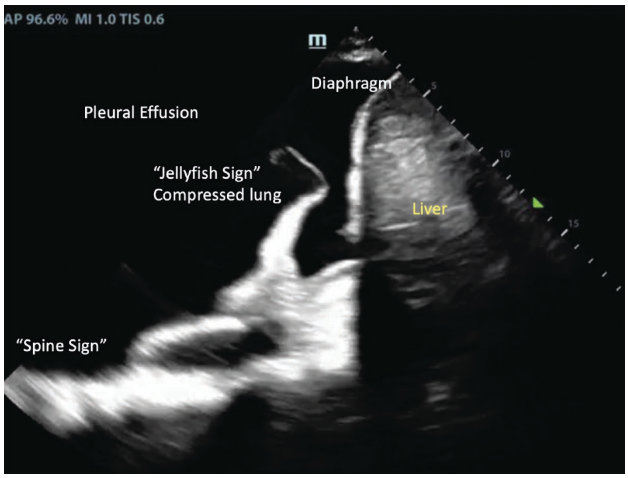
B lines are vertical "comet tail" streaking artifacts that extend from the pleura. Bilateral, diffuse B lines are a very sensitive finding for pulmonary edema. While B lines artifacts are not specific for pulmonary edema, a diffuse distribution in the setting of other exam findings of volume overload increases the specificity.

2. Pleural effusion



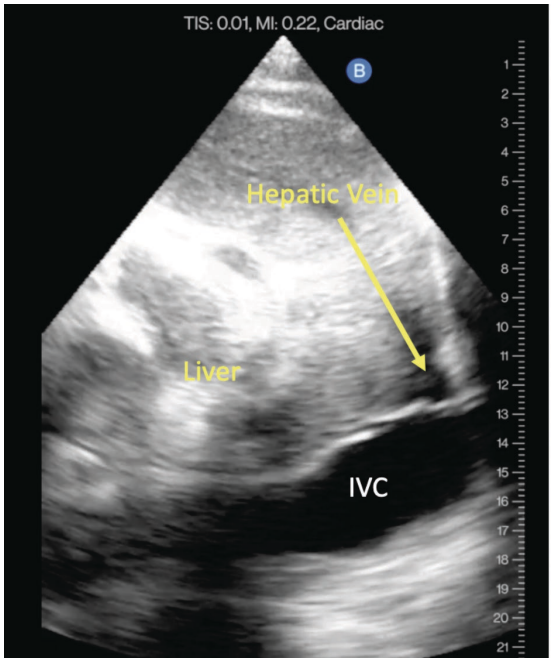
Pleural effusions are hypoechoic spaces best seen at the pleural bases while the patient is sitting upright. Pictured here is a large pleural effusion that appears filled with simple, transudative fluid (there are no hyperechoic residues or septations to suggest a complicated effusion). However, a thoracentesis and fluid sampling would be needed for confirmation. The "spine sign" points out the thoracic spine. The thoracic spine is well visualized in pleural effusions because the fluid provides an excellent medium for sound travel. In healthy lungs, the air disrupts sound transmission, thus preventing the spine from being imaged.

3. Pleural effusion



In pleural effusion, the lung tissue can be compressed and there can be atelectatic lung. The hydrostatic pressure from the effusion will fold and condense the lung tissue, and this abnormal lung tissue can be visualized floating in the effusion, similar to a jellyfish.

4. Plethoric IVC



This patient's IVC is >21mm in diameter and did not decrease by 50% with inspiration. This estimates a severely elevated right atrial pressure of > 15mmHg, per Rudski et al.

Pitfalls and Pearls

1. B lines are a non-specific finding. B lines are caused by an interstitial lung process, which thus disrupts the A-line artifacts seen in healthy lung tissue. However, this fluid could be due to pulmonary edema, as in heart failure, or due to inflammatory fluid or pus, as in pneumonia.

2. The presence of B lines will tell you that there is not a pneumothorax at that location. The presence of air between the visceral and parietal lung pleura would prevent B lines from being visualized because of that new air interface.

3. If you have a unilateral effusion, examine the lower lung lobes for consolidation. If there is a consolidation, then ultrasound the effusion thoroughly to identify signs of exudate or septations that may suggest an empyema, which would require sampling and drainage of that fluid.

4. The IVC evaluation alone is not a substitute for a comprehensive volume exam. There are also clinical conditions that confound the IVC evaluation. For example, tricuspid valve pathology, such as regurgitation can lead to a dilated IVC even in a hypovolemic state. A pericardial effusion or tamponade can also lead to a plethoric IVC.

5. When using the IVC to aid in your volume exam, the most practical information comes from whether it is plethoric (>21mm diameter and not decreasing with inspiration) or flat (<21mm diameter and collapsing with inspiration). By Rudski's criteria, a plethoric IVC described in this way would estimate a right atrial pressure of >15mmHg; the flat IVC would estimate a right atrial pressure of 3.

Acknowledgments:

The ultrasound images were acquired by Dr. Saati, Dr. Cooper, Dr. Foster, and Dr. Dong.

REFERENCES

1. Maw AM, Hassanin A, Ho PM, et al. Diagnostic Accuracy of Point-of-Care Lung Ultrasonography and Chest Radiography in Adults With Symptoms Suggestive of Acute Decompensated Heart Failure: A Systematic Review and Meta-analysis. *JAMA Netw Open*. 2019;2(3):e190703. doi:10.1001/jamanetworkopen.2019.0703.
2. Soni NJ, Franco R, Velez MI, et al. Ultrasound in the diagnosis and management of pleural effusions. *J Hosp Med*. 2015;10(12):811-816. doi:10.1002/jhm.2434.
3. Blackmore CC, Black WC, Dallas RV, Crow HC. Pleural fluid volume estimation: a chest radiograph prediction rule. *Acad Radiol*. 1996;3(2):103-109. doi:10.1016/s1076-6332(05)80373-3.
4. Gryminski J, Krakówka P, Lypacewicz G. The diagnosis of pleural effusion by ultrasonic and radiologic techniques. *Chest*. 1976;70(1):33-37. doi:10.1378/chest.70.1.33.
5. Röthlin MA, Näf R, Amgwerd M, Candinas D, Frick T, Trentz O. Ultrasound in blunt abdominal and thoracic trauma. *J Trauma*. 1993;34(4):488-495. doi:10.1097/00005373-199304000-00003.
6. Kalokairinou-Motogna M, Maratou K, Paianid I, et al. Application of color Doppler ultrasound in the study of small pleural effusion. *Med Ultrason*. 2010;12(1):12-16.
7. Rudski LG, Lai WW, Afilalo J, et al. Guidelines for the echocardiographic assessment of the right heart in adults: a report from the American Society of Echocardiography endorsed by the European Association of Echocardiography, a registered branch of the European Society of Cardiology, and the Canadian Society of Echocardiography. *J Am Soc Echocardiogr*. 2010;23(7):685-713; quiz 786. doi:10.1016/j.echo.2010.05.010.
8. O'Hara DN, Chabra V, Ahmad S. Bedside Ultrasound for Guiding Fluid Removal in Patients with Pulmonary Edema: The Reverse-FALLS Protocol. *J Vis Exp*. 2018;(137). doi:10.3791/57631.
9. Kimura BJ, Yogo N, O'Connell CW, Phan JN, Showalter BK, Wolfson T. Cardiopulmonary limited ultrasound examination for "quick-look" bedside application. *Am J Cardiol*. 2011;108(4):586-590. doi:10.1016/j.amjcard.2011.03.091.