Curr Emerg Hosp Med Rep (2016) 4:192–199
DOI 10.1007/s40138-016-0119-9

Echocardiography for ED Dyspnea Evaluation

Jennifer Carnell[1] · **Edwin Wu**[1]

Published online: 15 October 2016

Abstract
Purpose of Review The undifferentiated dyspneic patient is one of the most common critically ill patients encountered by hospital providers and continues to present a diagnostic challenge. Since its advent, bedside ultrasonography has demonstrated increasing clinical utility in identifying cardiopulmonary causes of dyspnea including left-sided heart failure, pulmonary edema, acute and chronic right-sided heart strain and failure, pneumonia, pleural fluid collections, airway processes such as chronic obstructive pulmonary disease, and cardiac tamponade. This review discusses the ability of point of care ultrasound to identify the cause of dyspnea in patients both in the emergency department, before hospitalization, and during hospitalization.
Recent findings Recent trends include demonstrable feasibility in novice users such as resident physicians and emergency triage nurses with no previous exposure to ultrasound and development of an automated algorithm to direct management of the dyspneic patient. Notable advances in employing ultrasound include demonstrable efficacy of multiorgan protocols, diaphragmatic assessment, and bedside echocardiography in elucidating the etiology of dyspnea. Recent evidence highlights ultrasound's diagnostic accuracy in identifying pulmonary edema and feasibility when using portable units and when performed by relatively inexperienced users.
Summary As ultrasound technology and its omnipresence in medicine advances, clinicians will encounter robust evidence that point of care ultrasound aids in understanding undifferentiated dyspnea. Additionally, providers will be exposed to novel uses of ultrasound that may advance patient care.

Keywords Point-of-care ultrasound · Dyspnea · Heart failure · Right heart dysfunction

Introduction

Dyspnea is a symptom that is commonly seen in patients with life threatening conditions of both cardiogenic and pulmonary causes and continues to be a diagnostic dilemma for the acute care physician and hospitalist. The differential diagnosis for these signs and symptoms is broad and includes pleural effusion, pneumothorax, pneumonia, cardiogenic pulmonary edema, chronic pulmonary hypertension, pulmonary embolism, pericardial effusion, primary pulmonary processes (i.e., exacerbation of chronic obstructive pulmonary disease, and asthma), and non-cardiogenic pulmonary edema (i.e., the acute respiratory distress syndrome). Using characteristic sonographic artifacts, lung ultrasound has established itself as a valuable tool in assessing the dyspneic patient by emergency physicians, intensivists, and internists. Moreover, multiple protocols exploit these findings to practically help guide management even after elucidating the underlying diagnosis. Since the

This article is part of the Topical collection on *Heart Failure*.

Electronic supplementary material The online version of this article (doi:10.1007/s40138-016-0119-9) contains supplementary material, which is available to authorized users.

✉ Jennifer Carnell
jencarnell@gmail.com

Edwin Wu
Edwin.wu33@gmail.com

[1] Emergency Medicine, Baylor College of Medicine, 1504 Taub Loop, Houston, TX 77006, USA

recognition of pulmonary parenchyma as tissue that is accessible by ultrasound, bedside lung sonography has gained widespread acceptance as an investigative modality that provides powerful diagnostic assistance. When coupled with bedside echocardiography and assessment of the inferior vena cava, ultrasonography is a tool that has shown increasing clinical utility with its expanding adoption. With its ascent in popularity, efforts have focused on assessing its ease of learning and efficacy in novice users and even computerized automation of its utility.

Trends in Sonographic Assessment of the Dyspneic Patient

Recent work has shown that in the hands of providers with no previous lung ultrasound experience, minimal tutorial is required to improve the diagnostic accuracy in patients with dyspnea. In a recent study, internal medicine residents were provided handheld ultrasound devices and obtained sonographic data from a convenience sample of patients admitted to their inpatient service with a complaint of dyspnea [1]. All participating residents underwent two, ninety minute didactic sessions with supervised bedside instruction in image acquisition. Two residents participated in an additional training period of two weeks on a critical care ultrasound elective rotation. Use of ultrasonography improved diagnostic accuracy when compared with clinical methods alone. Furthermore, the participants who underwent extended training demonstrated incremental improvement in sensitivity of diagnosis of pleural effusions (Fig. 1, video 1) and exacerbations of chronic obstructive pulmonary disease/asthma. These data suggest that skills in lung ultrasound can be acquired with minimal training and incremental training can yield further diagnostic benefit. With the advent of lung ultrasound as a powerful clinical aid, there has been recent suggestion of the need to develop standards of training and education regarding lung ultrasonography [2].

In addition to internal medicine residents, recent work has shown diagnostic accuracy when bedside lung ultrasound is performed by experienced emergency nurses [3]. Two emergency triage nurses assessed a total of 106 patients with a chief complaint of dyspnea, of which ninety were included in final statistical analysis. Utilizing the Bedside Lung Ultrasound in Emergency (BLUE) Protocol, an internationally accepted protocol of investigating acute respiratory failure with ultrasound [4•], patients were categorized as having dyspnea of cardiac or non-cardiac origin. These impressions were compared to a criterion diagnosis ascribed by an emergency physician at the conclusion of the clinical encounter. Sensitivity and specificity approached 100 % with a positive likelihood ratio of 22.41. This pilot study's findings suggest that lung ultrasound helps nursing staff form an accurate clinical impression, potentially facilitating expeditious and appropriate treatment of the critically ill.

As lung ultrasound gains widespread acceptance as a diagnostic tool, there are increasing numbers of novice users. As a result, technologic advances have been explored that may help bolster the clinical confidence to act on sonographic findings. A sonographic artifact seen in

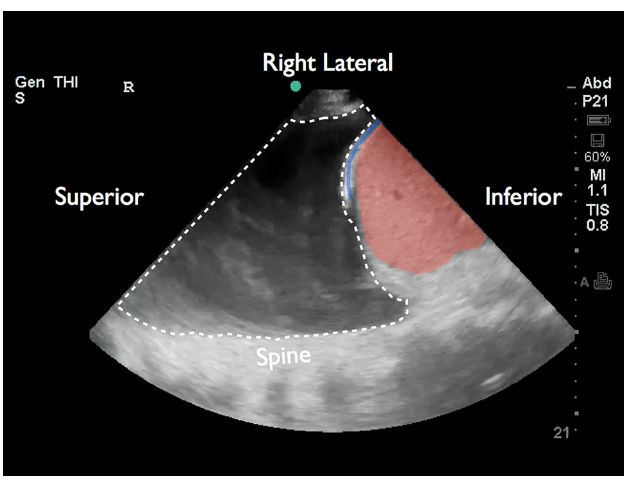

Fig. 1 Pleural effusion. The liver is identified by the area of *red shading*. Superior to the liver, the lateral portion of the right diaphragm is identified by the overlying *blue line*. Superior to the diaphragm, an anechoic or *black area* is outlined by the *white dashed line* and represents fluid in the pleural space. Due to the presence of fluid in the pleural space, which is an excellent conductor of ultrasound waves, the spine can be visualized *midline*. The spine would not be visualized through normal aerated lung as air scatters ultrasound waves. [See Supplemental Video 1] (Color figure online)

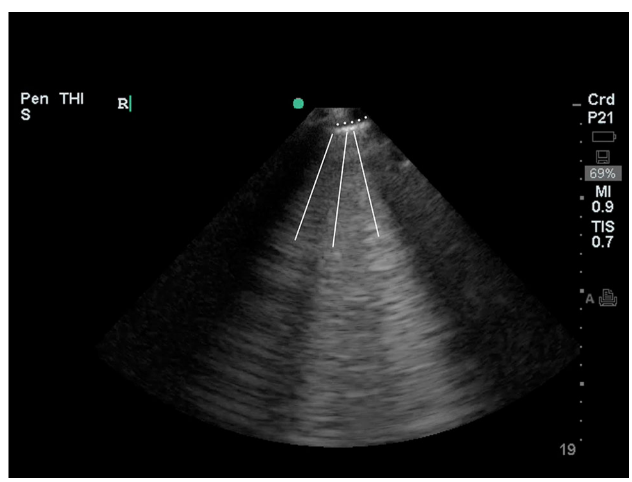

Fig. 2 B Lines. The *dotted white line* delineates the pleural line where the parietal and visceral pleura are opposed. The *solid white lines* indicate the initial trajectory of B lines, vertical hyperechoic lines, which originate at the pleural line and are indicative of interstitial fluid in the lung. [See Supplemental Video 2]

lung ultrasound images that is highly suggestive of pulmonary interstitial fluid, most commonly caused by acute heart failure, is the "B line." B lines appear as echogenic vertical lines that arise from and move with the pleural line, extending to the edge of the screen (usually to a depth of 16 to18 cm (Fig. 2, video 2). B-line counts of three or greater within a single intercostal space correlate with clinically significant interstitial edema. Brattain et al. [5] developed and validated a computerized algorithm from video clips derived from a large emergency ultrasound training study. This automated algorithm identified B lines quantitatively and achieved 100 % accuracy in scoring video clips selected by clinicians as having no B lines to multiple B lines. The development of a computerized algorithm may aid in future education and training of novice users via standardization of B-line quantification.

Bedside lung ultrasound has gained significant widespread acceptance among clinicians as a portable diagnostic modality with minimal risk but significant utility in diagnosing critical causes of dyspnea. Future directions should include consideration of training, education and its use by novice providers, potentially aided with computerized automation.

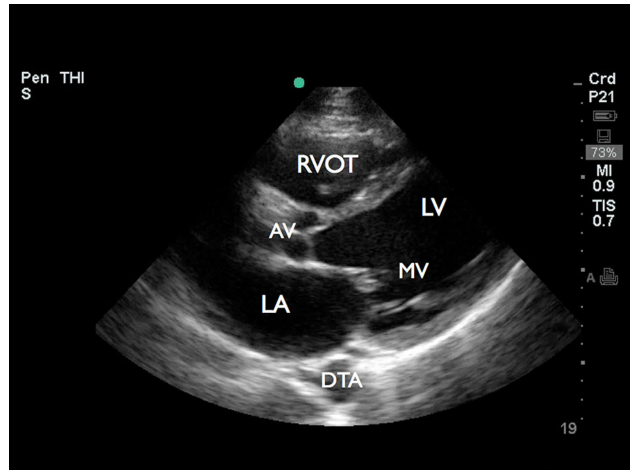

Fig. 3 Poor left ventricular ejection fraction. This parasternal long view of the heart was obtained by placing the phased array probe to the left of sternum at approximately the fourth intercostal space with the indicator pointed toward the patient's right shoulder. The left atrium (LA), mitral valve (MV), left ventricle (LV), aortic valve (AV), right ventricular outflow tract (RVOT), and descending thoracic aorta (DTA) are all seen in this image. This parasternal long view demonstrates poor left ventricular systolic function as evidenced by minimal inward movement of the walls of the left ventricle and significantly diminished excursion of the anterior leaflet of the mitral valve. [See Supplemental Video 3]

Methods in Using Ultrasound in Evaluating the Dyspneic Patient

Chest radiography is often unable to differentiate a cardiogenic edematous infiltrate from an infectious infiltrate. Specifically, in the setting of pulmonary edema, it is often impossible to exclude underlying infection using the chest radiograph. It has recently been demonstrated that B-line scores ascertained from the BLUE protocol are significantly higher in patients with an infectious pneumonia with concomitant acute left ventricular heart failure than those with an isolated pneumonia [6]. These bedside data are easily obtained from four standardized BLUE protocol views of the lungs and provide actionable clinical data. When using a B-line score cutoff value of 8, the sensitivity and specificity of accurately diagnosing pneumonia with acute left ventricular heart failure was 80.7 and 100 %, respectively.

Several recent studies have used integrated multiorgan examinations to elucidate the underlying cause of dyspnea. Mantuani et al. [7•] describe a Triple Scan consisting of bedside echocardiography (parasternal long, short axis and/or apical 4-chamber), 4-point lung scan (consisting of the bilateral anterior lung windows), and assessment of inferior vena cava (IVC) collapsibility. A priori sonographic findings were established with each diagnosis consisting of a constellation of ultrasound findings [8•]. The presence of B lines bilaterally, poor left ventricular systolic function

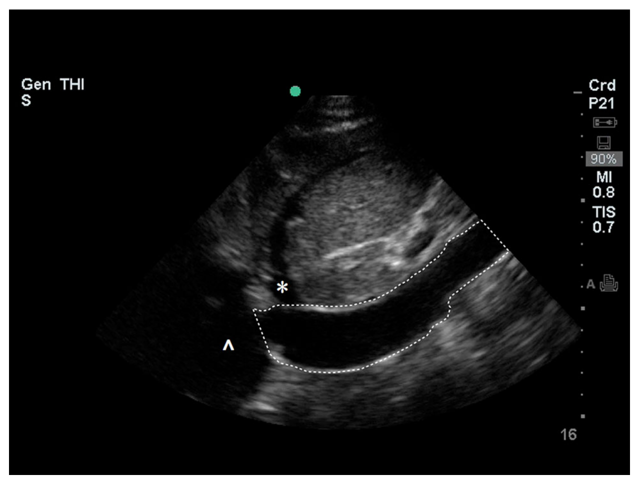

Fig. 4 The inferior vena cava is outlined by the *white dashed line*. The hepatic vein, seen entering the inferior vena cava, is indicated by the asterisk (*). The right atrium, into which the inferior vena cava enters, is marked by a caret (^). The inferior vena cava seen here is plethoric; it is large caliber and does not vary in size with respirations. Such an inferior vena cava may be seen in a patient with an obstructive process such as heart failure, cardiac tamponade, massive pulmonary embolus, or tension pneumothorax. [See Supplemental Video 4]

(Fig. 3, video 3), and a non-respirophasic IVC (Fig. 4, video 4) defined acute decompensated heart failure. Absence of B lines, normal to poor cardiac function with a non-respirophasic or flat IVC (Fig. 5, video 5) defined COPD. Unilateral B-lines or lung consolidation with

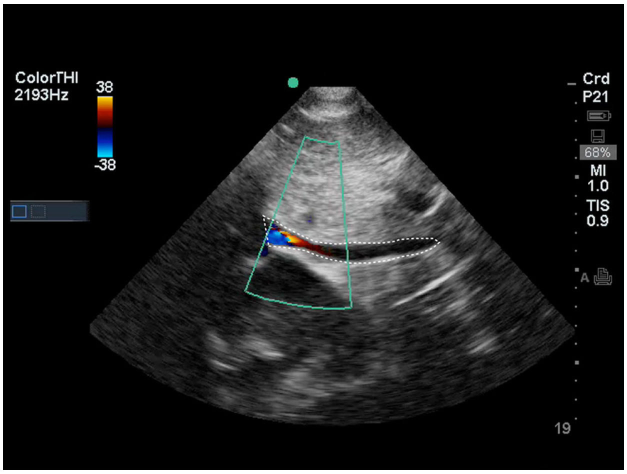

Fig. 5 Flat inferior vena cava. The inferior vena cava is outlined by the *white dashed line*. While not necessary to visualize the inferior vena cava, color doppler has also been placed on this image and demonstrates blood flow within the inferior vena cava. The inferior vena cava seen here is small caliber and nearly collapses with respirations. Such an inferior vena cava may be seen in a hypovolemic patient who is dehydrated from a process such as diabetic ketoacidosis, significant gastrointestinal losses, sepsis, or hemorrhage. [See Supplemental Video 5] (Color figure online)

normal or hyperdynamic left ventricular systolic function and a non-plethoric IVC defined the sonographic diagnosis of pneumonia. Treating physicians were asked to give their most likely diagnosis after history and physical examination and before serum or radiographic investigations resulted. After performing and disclosing the triple scan results to the treating physician, the overall diagnostic accuracy improved from 53 to 77 %. The clinical data provided by the triple scan also demonstrated 100 % sensitivity and 84 % specificity for the diagnosis of acute decompensated heart failure.

An integrated Lung and Cardiac UltraSound (LUCUS) protocol described by Russell et al. [9] demonstrated 83 % sensitivity and specificity with a positive likelihood ratio of 4.8 in the diagnosis of acute decompensated heart failure as the cause of dyspnea. This protocol utilized 12 views in total and required a mean of 12 minutes to perform. The findings from the LUCUS protocol resulted in changes in acute management (i.e., a new consult) in 47 % of patients and treatment in 42 % (i.e., discontinuation of albuterol or cessation of intravenous fluid administration).

In a study evaluating left ventricular ejection fraction, inferior vena cava collapsibility and pleural B lines, Anderson et al. [10•] demonstrated a 100 % specificity for the diagnosis of acute left heart failure as the cause of dyspnea in one hundred and one emergency department patients with a complaint of shortness of breath. Combining an ejection fraction cutoff of 45 %, an inferior vena cava collapsibility index of less than 20 % and a total B-line score of at least 10 B lines, his group demonstrated a sensitivity of 36 % and a specificity of 100 % for diagnosing acute decompensated heart failure as the etiology of dyspnea. This is compared to a sensitivity of 75 % and a specificity of 83 % when using a brain natriuretic peptide cutoff of 500.

In addition to examination of cardiac function, inferior vena cava collapsibility, and pulmonary parenchyma, recent work has evaluated diaphragmatic function and correlated it with pulmonary performance measures in both normal subjects and patients afflicted with chronic obstructive pulmonary disease.

Boon et al. [11] evaluated one hundred and fifty normal subjects and ascertained their diaphragmatic thickness using a high-frequency linear probe. A diaphragmatic thickness of 0.15 cm at end expiration or functional residual capacity with a greater than 20 % increase in thickness from functional residual capacity to total lung capacity is normal. Additionally, these values are minimally affected by age, gender, body mass index, or smoking history.

A recent study investigated the association of diaphragmatic excursion, measured as the difference in position of the end-expiratory and end-inspiratory lung silhouette (the margin of aerated parenchyma interfaced with the liver or spleen on the right and left sides, respectively), with forced expiratory volume over 1-second (FEV1) [12]. Using ultrasound, the lung margin is identified and the patient is asked to inhale maximally, then exhale maximally. The change in distance of the lung silhouette was then measured using electronic calipers. In a twenty-person cohort each of COPD GOLD class II, III, and IV and a twenty-person cohort of normal subjects, it was noted that with incremental worsening in GOLD class status, ultrasonographic measurement of diaphragmatic excursion decreased. When plotted against their FEV1, there was strong correlation.

Ultrasound assessment of diaphragmatic dysfunction is a novel investigative modality in the assessment of the dyspneic critically ill patient. Like all novel modalities, its utility is predicated on its reproducibility. Smargiassi et al. [13] measured diaphragmatic thickness at varying lung volumes. Their data showed good intra-observer reproducibility suggesting that the assessment of diaphragmatic thickness is feasible. Furthermore, their data suggested that lower diaphragmatic thickness and lower diaphragmatic thickening at total lung capacity are seen in patients with a higher degree of air trapping and with weakening of skeletal muscle, specifically the diaphragm, as muscle atrophy occurs in COPD. In the dyspneic patient, ultrasound measurements of diaphragmatic excursion and thickness may identify diaphragmatic dysfunction as the cause of the patient's respiratory symptoms.

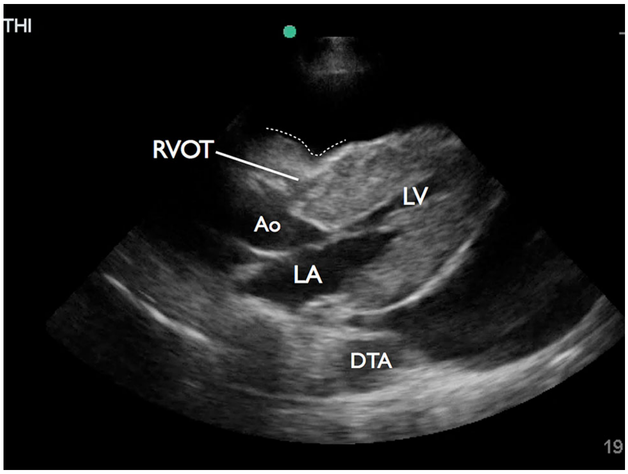

Fig. 6 Pericardial effusion and tamponade. This parasternal long view of the heart was obtained by placing the phased array probe to the left of sternum at approximately the fourth intercostal space with the indicator pointed toward the patient's right shoulder. The left atrium (LA), left ventricle (LV), aorta (Ao), right ventricular outflow tract (RVOT), and descending thoracic aorta (DTA) are all seen in this image. This parasternal long view demonstrates right ventricular diastolic collapse as evidenced by the inward scalloping of the free wall of the right ventricle (*dashed white line*) and near complete compression of the RVOT. The heart is surrounded by a circumferential pericardial effusion which is anechoic (*black*). An incidental finding of left ventricular hypertrophy, with the left ventricular wall appearing to have a thickness over 1 cm, is also seen. [See Supplemental Video 6]

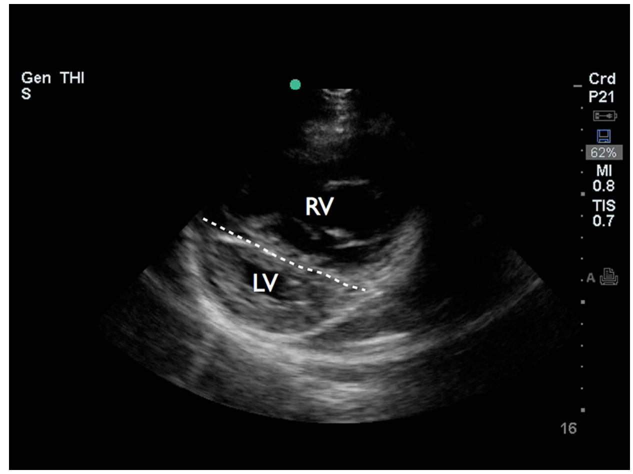

Fig. 7 Right heart strain. This parasternal short view of the heart was obtained by placing the phased array probe to the left of sternum at approximately the fourth intercostal space with the indicator pointed toward the patient's left shoulder. The left ventricle (LV), right ventricle (RV), and interventricular septum (*dashed white line*) are all seen in this image. This parasternal short view demonstrates a dilated right ventricle and flattening of the interventricular septum, both findings indicative of right heart dysfunction. These findings may be seen in the presence of acutely elevated pulmonary pressures, as in pulmonary embolism, or chronic pulmonary hypertension. In chronic right heart dysfunction, hypertrophy of the right ventricle may be noted via a right ventricular wall thickness that exceeds 0.5 cm, the upper limit of normal for RV wall thickness. [See Supplemental Video 7]

Pericardial effusion with concomitant tamponade (Fig. 6, video 6) is an extra-pulmonary etiology of dyspnea that is readily diagnosed using bedside ultrasonography. Investigators have begun utilizing ultrasonography to identify tamponade as the culprit etiology in dyspneic patients with confounding clinical circumstances. Recently, Vallabhajosyula et al. [14] reported identifying cardiac tamponade as the etiology of dyspnea in a patient with severe, chronic pulmonary hypertension, preventing the committal of the cognitive error of premature diagnostic closure in a complex patient. Cheng et al. [15] identified a pericardial effusion with early tamponade as the initial presentation of systemic lupus erythematosus. Recent work has demonstrated its utility in helping guide management of confounding cases of dyspnea. When a patient's dyspnea is unexplained after emergency department work up for pulmonary, infectious, hematological, traumatic, psychiatric, cardiovascular, or neuromuscular etiologies, emergency providers and hospitalists should evaluate for pericardial effusion. In a group of 103 patients with unexplained dyspnea, 14 (13.6 %) were found to have pericardial effusions. 7 (49 %) of the patients were admitted to the hospital for moderate to large effusions and all 4 patients with large effusions underwent pericardiocentesis [16].

Evidence of pulmonary embolism (PE) as the etiology for dyspnea can also be detected on ultrasound examinations. Most practitioners envision using echocardiography to detect signs of right heart strain suggestive of the presence of PE (Fig. 7, video 7). In a retrospective study of emergency physician-performed transthoracic echocardiography (TTE), the presence of right heart strain was the most important predictor of in-hospital adverse events with an odds ratio of 9.2 [17]. In a study of normotensive PE patients, goal-directed echocardiography at bedside detected right ventricular dysfunction with a high accuracy exceeding that of biomarkers (BNP, troponin) and CT [18••]. In the study, bedside goal-directed echocardiography performed by ED providers had a sensitivity of 100 % and a specificity of 99 % for right ventricular dysfunction when compared to comprehensive echocardiography. Mansecal et al. demonstrated that an EM provider-performed TTE and lower extremity venous ultrasound for deep venous thrombosis (DVT) had a sensitivity of 97 % for PE in a subset of patients with dyspnea [19]. In a subsequent study, multiorgan ultrasound of the heart, lungs, and leg veins yielded a sensitivity of 90 % and a specificity of 86.2 % for PE when compared to multi-detector computed tomography pulmonary angiography (MCTPA) [20]. All multiorgan ultrasound exams were performed prior to CT and were considered positive for PE, if subpleural infarct, RV dilation, or DVT were present.

Ultrasound, specifically TTE, serves not only to help diagnose PE but also to explain dyspnea in the absence of PE by detecting RV dysfunction. Kline and colleagues evaluated a group of patients with persistent dyspnea despite CT negative for PE. They found that the combination of a negative CT for PE and persistent dyspnea had a positive predictive value of 53 % for isolated RV dysfunction or overload on echo [21]. Thus, TTE should be considered in patients who remain symptomatic despite a negative CT for PE as earlier diagnosis and work up of isolated RV dysfunction and pulmonary hypertension may improve outcomes.

Evidence Guiding the Use of Ultrasound in Dyspnea

A recent systematic review and meta-analysis of the literature examining the utility of ultrasound in diagnosing acute cardiogenic pulmonary edema (ACPE) in dyspneic patients showed a sensitivity of 94.1 % and a specificity of 92.4 % when compared to the final diagnosis established in follow-up [22]. The studies were conducted in the emergency department, intensive care unit, and prehospital setting. The presence of B lines on lung ultrasound increases the likelihood that the cause of dyspnea is acute cardiogenic pulmonary edema in patients with a moderate to high pretest probability of ACPE. Alternatively, in patients with a low pretest probability, the absence of B lines on lung ultrasound virtually rules out acute cardiogenic pulmonary edema as the etiology.

Essential to the applicability of any clinical technique is its ease of use and reproducibility. Gullett et al. [23] compared expert/expert pairings of emergency sonologists to expert/novice pairings and evaluated interobserver reliability in sonographic B-line assessment and interpretation in patients with undifferentiated shortness of breath. This study was unique in that all evaluations were performed realtime as opposed to studies that evaluate B lines via review of previously recorded ultrasound exams. Overall, there was excellent interobserver agreement in the anterior/superior lung zones, but poor agreement in the lateral lower lung zones. Experience did not appear to affect interrater reliability. Chiem et al. [24] compared novice sonographers to one expert sonographer's ability to assess for B lines. The novice group was comprised of 66 EM residents with basic emergency medicine ultrasound training without any prior training in lung ultrasound for B lines. They received a 30-min training in thoracic ultrasound for the detection of B lines prior to participating in the study. The novices were able to obtain adequate images in nearly all patients (95 % of the time). Furthermore, they showed very good agreement with expert interpretation of their images. Receiver operator characteristic analysis showed similar areas under the curve between novice and expert sonographers, indicating that B-line assessment in lung ultrasound is a feasible and reproducible method even in the hands of novice sonographers.

Comparison of resident physicians' abilities to identify pulmonary edema using lung ultrasound or chest radiography was examined [25]. In a prospective, blinded, observational study comparing the accuracy of diagnosis of pulmonary edema using the aforementioned modalities (after a brief tutorial in interpreting each for pulmonary edema), residents in emergency medicine, internal medicine and radiology all identified pulmonary edema on lung ultrasound with greater overall accuracy than chest radiography, supporting that physicians with minimal exposure to lung sonography can utilize it to diagnose pulmonary edema.

In a large, multicenter, prospective cohort study, use of lung ultrasound in concert with clinical assessment demonstrated superior diagnostic accuracy when compared to clinical assessment alone, chest radiography alone, and natriuretic peptides [26] in differentiating acute decompensated heart failure from non-cardiogenic dyspnea. When lung ultrasound was used in conjunction with initial clinical workup, sensitivity was 97 % and specificity was 97.4 %. In another recent study, Gallard et al. [27] demonstrated diagnostic accuracy of 90 % in emergency patients with acute dyspnea. In addition to accurately diagnosing cardiogenic pulmonary edema, treating clinicians utilizing ultrasound also identified other causes of dyspnea including pneumonia, pleural effusion, and decompensated chronic obstructive pulmonary disease and asthma.

In patients with tachypnea, dyspnea, or hypoxemia on pulse oximetry, point-of-care ultrasound of the heart, lungs, and deep veins identified acute life threatening causes after initial workup and admission with a sensitivity of 100 %, specificity of 93.3 %, positive predictive value of 76.7 %, and a negative predictive value of 100 % [28•]. In a prospective, parallel group, randomized control trial conducted by the same investigators, patients receiving a point-of-care ultrasound of the heart, lungs, and deep veins had significantly higher rates of correct diagnoses and appropriate treatment initiation within four hours after admission to the emergency department for respiratory symptoms than patients receiving only standard diagnostic tests [29•]. In an intensive care unit population of 128 patients with pulmonary edema, the group randomized to integrated cardiopulmonary ultrasound had a shorter time to determination of cause of pulmonary edema and received smaller fluid infusion volumes overall. In the subset of patients with cardiogenic pulmonary edema, ICU lengths of stay were significantly shorter and return to normal cardiac biomarker levels occurred more rapidly [30]. This study did not demonstrate a significant difference in mortality.

New, more compact, and portable technologies are emerging. In a small study examining the utility of handheld portable ultrasounds in performing cardiac examinations, Mancuso et al. [31] demonstrated that rapid confirmation of the initial suspected diagnosis could be achieved, potentially expediting management of critical pathology. In another study examining the accuracy of portable, handheld ultrasound in emergency patients presenting with dyspnea, an integrated lung, cardiac, and inferior vena cava exam displayed sensitivity of 94.3 %, specificity of 91.9 %, positive predictive value of 91.9 %, and a negative predictive value of 94.3 % in diagnosing acute heart failure as the etiologic entity [32].

While cardiopulmonary ultrasonography demonstrates great promise as a diagnostic tool, there is equipoise within the literature. Trovato et al. [33] examined the utility of thoracic ultrasound in differentiating a cardiogenic etiology from other causes in two-hundred and eighty-three consecutive patients when compared to two-hundred and fifty healthy control subjects. These investigators demonstrated that while a greater number of B lines were seen in the dyspneic patients, no sonographic feature, average number of B lines scored, or criterion cutoff distinguished acute cardiogenic pulmonary edema from non-cardiac causes of dyspnea. Brown et al. [34] cautions against unbridled adoption of cardiopulmonary ultrasonography as the dominant modality in managing shock, respiratory failure, and diagnosis establishment in dyspnea as its value has not yet been well validated. Another cautionary message is that while ultrasound is thought to be risk free, its true danger lies in committing cognitive errors of interpretation with the vividness of visual imagery on the display [34].

Conclusions

Cardiopulmonary ultrasonography has now been widely adopted as an investigative bedside modality that provides timely, radiation-free clinical data that are reproducible and actionable. It can be performed in a serial manner, guiding clinicians in the immediate management and the assessment of clinical changes in the critically ill patient. Development of educational materials and training standards is rapidly occurring. Protocolized methods are beginning to develop and with new technological advances such as a computerized diagnostic assistance and increasing portability, cardiopulmonary ultrasound is poised for incorporation into the daily medical practice of the acute care physician and hospitalist.

Compliance with Ethical Guidelines

Conflict of Interest Drs Carnell and Wu declare that they have no conflicts of interests.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by the author.

References

Papers of particular interest, published recently, have been highlighted as:
- • Of importance
- •• Of major importance

1. Filopei J, Siedenburg H, Rattner P, Fukaya E, Kory P. Impact of pocket ultrasound use by internal medicine housestaff in the diagnosis of dyspnea. J Hosp Med. 2014;9(9):594–7.
2. Karim A, Arora VK. Applications of ultrasonography in respiratory intensive care. Indian J Chest Dis Allied Sci. 2014;56(1):27–31.
3. Ünlüer EE, Karagöz A, Oyar O, Vandenberk N, Kiyançiçek S, Budak F. Lung ultrasound by emergency nursing as an aid for rapid triage of dyspneic patients: a pilot study. Int Emerg Nurs. 2014;22(4):226–31.
4. • Lichtenstein DA. BLUE-protocol and FALLS-protocol: two applications of lung ultrasound in the critically ill. Chest. 2015;147(6):1659–1670. *Describes the use of two point of care ultrasound protocols, specifically (1) the BLUE protocol to ascertain the cause of acute dyspnea/respiratory distress and (2) the FALLS protocol to ascertain the etiology of shock.*
5. Brattain LJ, Telfer BA, Liteplo AS, Noble VE. Automated B-line scoring on thoracic sonography. J Ultrasound Med. 2013;32(12):2185–90.
6. Liu ZP, Zhang Y, Bian H, He XR, Zhou YJ, Wang LJ, Ding N. Clinical application of rapid B-line score with lung ultrasonography in differentiating between pulmonary infection and pulmonary infection with acute left ventricular heart failure. Am J Emerg Med. 2016;34(2):278–81.
7. • Mantuani D, Nagdev A, Stone M. Three-view bedside ultrasound for the differentiation of acute respiratory distress syndrome from cardiogenic pulmonary edema. Am J Emerg Med. 2012;30(7):1324.e1–4. *Discusses the use of bedside ultrasound of the heart, lungs and inferior vena cava to differentiate between acute respiratory distress syndrome and cardiogenic pulmonary edema.*
8. • Mantuani D, Frazee BW, Fahimi J, Nagdev A. Point-of-Care Multi-Organ Ultrasound Improves Diagnostic Accuracy in Adults Presenting to the Emergency Department with Acute Dyspnea. West J Emerg Med. 2016;17(1):46–53. *A multiorgan ultrasound protocol that used imaging of the heart, lungs and inferior vena cava to immediately improve the treating provider's diagnostic accuracy for acute decompensated heart failure, COPD/asthma and pneumonia and was most useful in excluding acute decompensated heart failure as the cause of acute dyspnea in the emergency department.*

9. Russell FM, Ehrman RR, Cosby K, Ansari A, Tseeng S, Christain E, Bailitz J. Diagnosing acute heart failure in patients with undifferentiated dyspnea: a lung and cardiac ultrasound (LuCUS) protocol. Acad Emerg Med. 2015;22(2):182–91.
10. • Anderson KL, Jenq KY, Fields JM, Panebianco NL, Dean AJ. Diagnosing heart failure among acutely dyspneic patients with cardiac, inferior vena cava, and lung ultrasonography. Am J Emerg Med. 2013;31(8):1208–1214. *Point of care ultrasound study that evaluated acutely dyspneic patients in the emergency department and demonstrated that the combination of ultrasound findings that included (1) left ventricular ejection fraction less than 45 %, (2) inferior vena cava collapsibility index less than 20 %, and (3) at least 10 B-lines had a sensitivity of 36 % and a specificity of 100 % in diagnosing acute decompensated heart failure.*
11. Boon AJ, Harper CJ, Ghahfarokhi LS, Strommen JA, Watson JC, Sorenson EJ. Two-dimensional ultrasound imaging of the diaphragm: quantitative values in normal subjects. Muscle Nerve. 2013;47(6):884–9.
12. Scheibe N, Sosnowski N, Pinkhasik A, Vonderbank S, Bastian A. Sonographic evaluation of diaphragmatic dysfunction in COPD patients. Int J Chron Obstruct Pulmon Dis. 2015;11(10):1925–30.
13. Smargiassi A, Inchingolo R, Tagliaboschi L, Di Marco Berardino A, Valente S, Corbo GM. Ultrasonographic assessment of the diaphragm in chronic obstructive pulmonary disease patients: relationships with pulmonary function and the influence of body composition—a pilot study. Respiration. 2014;87(5):364–71.
14. Vallabhajosyula S, Sundaragiri PR. Atypical cardiac tamponade in severe pulmonary hypertension. BMJ Case Rep. 2015;. doi:10.1136/bcr-2014-209187.
15. Cheng W, Balachandar R, Mistry P. Cardiac tamponade: an initial presentation of SLE. BMJ Case Rep. 2013;2013:18.
16. Blaivas M. Incidence of pericardial effusion in patients presenting to the emergency department with unexplained dyspnea. Acad Emerg Med. 2001;8(12):1143–6.
17. Taylor RA, Moore CL. Accuracy of emergency physician-performed limited echocardiography for right ventricular strain. Am J Emerg Med. 2014;32(4):371–4.
18. •• Weekes AJ, Thacker G, Troha D, Johnson AK, Chanler-Berat J, Norton HJ, Runyon M. Diagnostic accuracy of right ventricular dysfunction markers in normotensive emergency department patients with acute pulmonary embolism. Ann Emerg Med. 2016;68(3):277–291. *Study that demonstrated that goal directed echocardiography in normotensive patients by emergency physicians had a sensitivity of 100 % and a specificity of 99 % for identifying early severe right ventricular dysfunction when compared to comprehensive echocardiography and was superior to biomarkers such as troponin and brain natriuretic protein and CT scan of the chest.*
19. Mansencal N, Vieillard-Baron A, Beauchet A, Farcot JC, El Hajjam M, Dufaitre G, Brun-Ney D, Lacombe P, Jardin F, Dubourg O. Triage patients with suspected pulmonary embolism in the emergency department using a portable ultrasound device. Echocardiography. 2008;25(5):451–6.
20. Nazerian P, Vanni S, Volpicelli G, Gigli C, Zanobetti M, Bartolucci M, Ciavattone A, Lamorte A, Veltri A, Fabbri A, Grifoni S. Accuracy of point-of-care multiorgan ultrasonography for the diagnosis of pulmonary embolism. Chest. 2014;145(5):950–7.
21. Kline JA, Russell FM, Lahm T, Mastouri RA. Derivation of a screening tool to identify patients with right ventricular dysfunction or tricuspid regurgitation after negative computerized tomographic pulmonary angiography of the chest. Pulm Circ. 2015;5(1):171–83.
22. Al Deeb M, Barbic S, Featherstone R, Dankoff J, Barbic D. Point-of-care ultrasonography for the diagnosis of acute cardiogenic pulmonary edema in patients presenting with acute dyspnea: a systematic review and meta-analysis. Acad Emerg Med. 2014;21(8):843–52.
23. Gullett J, Donnelly JP, Sinert R, Hosek B, Fuller D, Hill H, Feldman I, Galetto G, Auster M, Hoffmann B. Interobserver agreement in the evaluation of B-lines using bedside ultrasound. J Crit Care. 2015;30(6):1395–9.
24. Chiem AT, Chan CH, Ander DS, Kobylivker AN, Manson WC. Comparison of expert and novice sonographers' performance in focused lung ultrasonography in dyspnea (FLUID) to diagnose patients with acute heart failure syndrome. Acad Emerg Med. 2015;22(5):564–73.
25. Martindale JL, Noble VE, Liteplo A. Diagnosing pulmonary edema: lung ultrasound versus chest radiography. Eur J Emerg Med. 2013;20(5):356–60.
26. Pivetta E, Goffi A, Lupia E, Tizzani M, Porrino G, Ferreri E, Volpicelli G, Balzaretti P, Banderali A, Iacobucci A, Locatelli S, Casoli G, Stone MB, Maule MM, Baldi I, Merletti F, Cibinel GA. SIMEU group for lung ultrasound in the emergency department in piedmont. lung ultrasound-implemented diagnosis of acute decompensated heart failure in the ED: a SIMEU multicenter study. Chest. 2015;148(1):202–10.
27. Gallard E, Redonnet JP, Bourcier JE, Deshaies D, Largeteau N, Amalric JM, Chedaddi F, Bourgeois JM, Garnier D, Geeraerts T. Diagnostic performance of cardiopulmonary ultrasound performed by the emergency physician in the management of acute dyspnea. Am J Emerg Med. 2015;33(3):352–8.
28. • Laursen CB, Sloth E, Lassen AT, Christensen Rd, Lambrechtsen J, Madsen PH, Henriksen DP, Davidsen JR, Rasmussen F. Point-of-care ultrasonography in patients admitted with respiratory symptoms: a single-blind, randomised controlled trial. Lancet Respir Med. 2014;2(8):638–646. *Addition of point-of-care ultrasonography of the heart, lungs, and deep veins to standard diagnostic tests produces statistically superior results in establishing a correct diagnosis within 4 hours of arrival in the emergency department.*
29. • Laursen CB, Sloth E, Lambrechtsen J, Lassen AT, Madsen PH, Henriksen DP, Davidsen JR, Rasmussen F. Focused sonography of the heart, lungs, and deep veins identifies missed life-threatening conditions in admitted patients with acute respiratory symptoms. Chest. 2013;144(6):1868–1875. *Focused sonography of the heart, lungs, and deep veins is able to diagnose life-threatening conditions missed at the primary assessment in 14 % of admitted patients with acute respiratory symptoms.*
30. Wang XT, Liu DW, Zhang HM, Chai WZ. Integrated cardiopulmonary sonography: a useful tool for assessment of acute pulmonary edema in the intensive care unit. J Ultrasound Med. 2014;33(7):1231–9.
31. Mancuso FJ, Siqueira VN, Moisés VA, Gois AF, Paola AA, Carvalho AC, Campos O. Focused cardiac ultrasound using a pocket-size device in the emergency room. Arq Bras Cardiol. 2014;103(6):530–7.
32. Kajimoto K, Madeen K, Nakayama T, Tsudo H, Kuroda T, Abe T. Rapid evaluation by lung-cardiac-inferior vena cava (LCI) integrated ultrasound for differentiating heart failure from pulmonary disease as the cause of acute dyspnea in the emergency setting. Cardiovasc Ultrasound. 2012;10(1):49.
33. Trovato GM, Sperandeo M. Sounds, ultrasounds, and artifacts: which clinical role for lung imaging? Am J Respir Crit Care Med. 2013;187(7):780–1.
34. Brown SM, Kasal J. Bedside Ultrasound in the Intensive Care Unit: Where Is the Evidence? Semin Respir Crit Care Med. 2015;36(6):878–89.