BRIEF REPORTS

Impact of Pocket Ultrasound Use by Internal Medicine Housestaff in the Diagnosis of Dyspnea

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BACKGROUND: Recent reports demonstrate high diagnostic accuracy of lung ultrasound for evaluation of dyspnea. We assessed the feasibility of training internal medicine residents in lung ultrasound with a pocket ultrasound device.

METHODS: We performed a prospective, observational trial of residents performing lung ultrasound with a pocket ultrasound. Training consisted of two 90-minute sessions of didactics and supervised bedside performance. Two residents received an additional 2 weeks of training. Residents recorded a clinical diagnosis based on admission data. Following lung ultrasound performance, an ultrasound diagnosis was recorded integrating clinical and sonographic findings. Using receiver operating curve analysis, the area under the curve was calculated for both clinical diagnosis and ultrasound diagnosis using attending physician's final discharge diagnosis as the gold standard.

RESULTS: Five residents performed 69 exams. The AUC for ultrasound diagnosis was significantly higher than that for clinical diagnosis (0.87 vs 0.81, $P < 0.01$). AUCs increased using lung ultrasound for diagnoses as follows: chronic obstructive pulmonary disease (0.73–0.85, $P = 0.06$), acute pulmonary edema (0.85–0.89, $P = 0.49$), pneumonia (0.77–0.88, $P = 0.01$), and pleural effusions (0.76–0.96, $P < 0.002$).

CONCLUSIONS: Lung ultrasound performed by residents with a pocket ultrasound improved the diagnostic accuracy of dyspnea. Two residents undergoing extended training showed a total increase in diagnostic accuracy. *Journal of Hospital Medicine* 2014;9:594–597. © 2014 Society of Hospital Medicine

Applications of point-of-care ultrasonography (POC-US) have grown rapidly over the past 20 years. POC-US training is required by the Accreditation Council for Graduate Medical Education for several graduate medical education training programs, including emergency medicine residency and pulmonary/critical care fellowships.[1] Recent efforts have examined the utility of ultrasound in the education of medical students[2] and the diagnostic and procedural applications performed by residents.[3] One powerful application of POC-US is the use of lung ultrasound to diagnose causes of respiratory failure at the bedside.[4] Although lung ultrasound has been shown to have superior diagnostic accuracy to chest x-rays,[5] limited availability of expert physicians and ultrasound equipment have presented barriers to wider application. The advent of lower cost pocket ultrasounds may present a solution given the early reports of similar efficacy to traditional devices in the assessment of left ventricular dysfunction, acute decompensated heart failure,[6] and focused assessment with sonography for trauma.[7] We

assessed the feasibility and diagnostic accuracy of residents trained in lung ultrasound with a pocket device for evaluating patients with dyspnea.

MATERIALS AND METHODS

Study Design

We performed a prospective, observational study of internal medicine residents performing lung ultrasound with a pocket ultrasound from September 2012 to August 2013 at Beth Israel Medical Center, an 856-bed teaching hospital in New York City. This study was approved by the Committee of Scientific Affairs of Beth Israel Medical Center, which waived the requirement for informed consent (institutional review board #016-10). Ten pocket ultrasounds (Vscan; GE Vingmed Ultrasound, Horten, Norway) were acquired through an educational grant from General Electric Company. Grant sponsors were not involved in any aspect of the study.

Recruitment and Training

One hundred nineteen internal medicine residents were offered training on lung ultrasound in return for participating in the study. Initially, 10 residents from 3 postgraduate years with no previous lung ultrasound experience volunteered for the study and received a pocket ultrasound along with either focused or extended training. Focused and extended training groups both received 2 sessions of 90 minutes that included didactics covering image creation of the 5 main diagnostic lung ultrasound patterns and their

Lung Ultrasound Pattern	Diagnosis
Bilateral diffuse A Lines[b] with sliding lung[c]	COPD / Asthma
Consolidation[d] or unilateral B Lines[e]	Pneumonia
Bilateral anterior or diffuse B Lines	Pulmonary Edema
Anechoic/ Hypoechoic space between diaphragm, chest wall, and lung tissue	Pleural Effusion[f]
Absence of lung sliding	Pneumothorax
Bilateral A Lines and sliding lung with DVT on formal study	Pulmonary Embolism

A.

Standardized 8 Point Lung Ultrasound Exam
*Red denotes probe posterior to patient

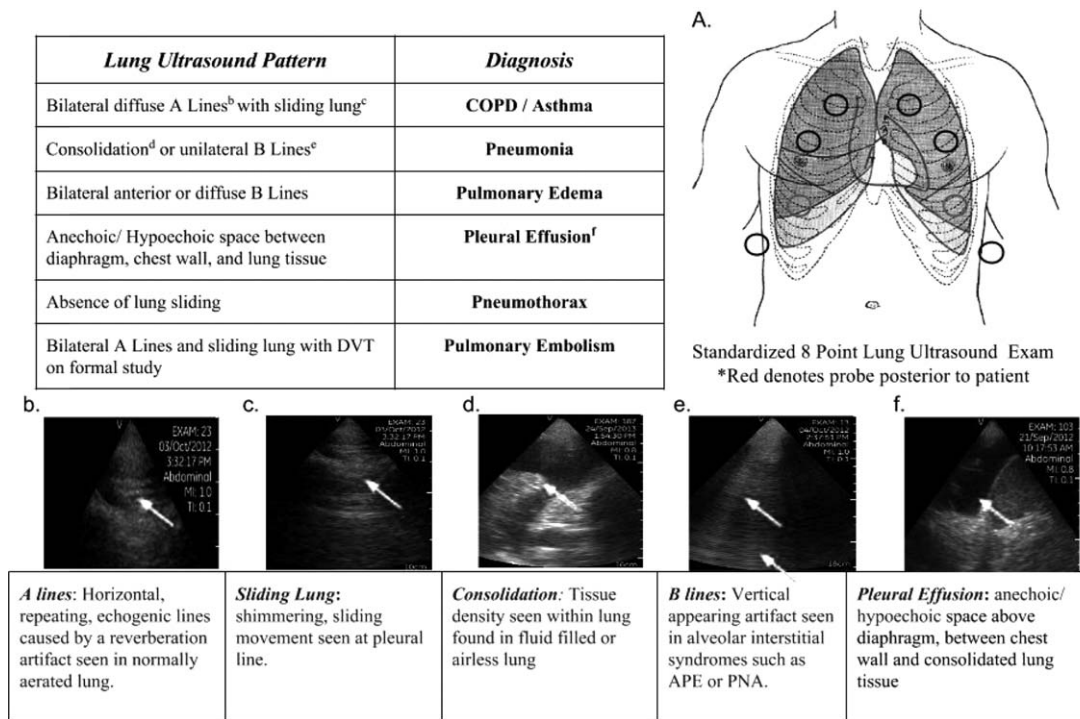| b.	c.	d.	e.	f.
A lines: Horizontal, repeating, echogenic lines caused by a reverberation artifact seen in normally aerated lung.	*Sliding Lung*: shimmering, sliding movement seen at pleural line.	*Consolidation*: Tissue density seen within lung found in fluid filled or airless lung	*B lines*: Vertical appearing artifact seen in alveolar interstitial syndromes such as APE or PNA.	*Pleural Effusion*: anechoic/ hypoechoic space above diaphragm, between chest wall and consolidated lung tissue

FIG. 1. Diagnostic correlate of lung ultrasound pattern.

pathological correlates. Sessions also included training in the operation of a pocket ultrasound along with bedside instruction in image acquisition using an 8-point exam protocol (Figure 1A). All residents were required to demonstrate competency in this 8-point protocol with proper image acquisition and interpretation of 3 lung ultrasound exams under direct supervision by an expert practitioner (P.K.). Only 5 residents completed the training due mostly to other commitments. Two extended training residents, both authors of this article, who plan to continue training in pulmonary and critical care medicine, volunteered for an additional 2-week general critical care ultrasound elective. This elective included daily bedside supervised performance and interpretation of lung ultrasound patterns on at least 15 patients admitted during intensive care unit rounds.

Patient Selection

Patients admitted to a resident's service were considered for inclusion at their convenience if the patient reported a chief complaint of dyspnea.

Diagnostic Protocol

Upon admission, residents recorded a clinical diagnosis of dyspnea based on a standard diagnostic evaluation including complete history, physical exam, and all relevant laboratory and imaging studies, including chest x-ray and computed tomography (CT) scans. A diagnosis of dyspnea after lung ultrasound was then recorded based on the lung ultrasound findings and integrated with all other clinical information

available. Standard lung ultrasound patterns and diagnostic correlates are shown in Figure 1. Diagnoses of dyspnea were recorded as one of 7 possibilities; 1) exacerbation of chronic obstructive pulmonary disease or asthma (COPD/asthma), 2) acute pulmonary edema (APE), 3) pneumonia (PNA), 4) pulmonary embolus (PE), 5) pneumothorax (PTX), 6) pleural effusion (PLEFF), and 7) other (OTH), namely anemia, ascites, and dehydration.

Data Collection

Patient demographics, comorbidities, lung ultrasound findings, and both clinical and ultrasound diagnosis were recorded on a standardized form. A final diagnosis based on the attending physicians' diagnosis of dyspnea was determined through chart review by 3 investigators blinded to the clinical and ultrasound diagnoses. Discordant findings were resolved by consensus. Attending physicians were blinded to the lung ultrasound exam results.

Statistical Analysis

Sensitivity and specificity of the clinical and ultrasound diagnoses for focused and extended training groups were calculated for each diagnosis using final attending diagnosis as the gold standard. Causes of dyspnea were often deemed multifactorial, leading to more than 1 diagnosis recorded per patient exam. Overall diagnostic accuracy was calculated for each group using the reported clinical, ultrasound, and final diagnoses. Receiver operating curve (ROC) analysis was performed with Stata 12.1 (StataCorp, College Station, TX).

RESULTS

Five residents performed lung ultrasound on a convenience sample of 69 newly admitted patients. Patient baseline characteristics are shown in Table 1. Three residents made up the focused training group and examined 21 patients, resulting in 27 clinical diagnoses, 27 ultrasound diagnoses, and 31 final attending diagnoses. Two residents made up the extended training group and examined 48 patients, resulting in 61 clinical diagnoses, 60 ultrasound diagnoses, and 60 final attending diagnoses. Improvements in sensitivity and specificity using lung ultrasound were more pronounced for the extended training group and are shown for each diagnosis in Table 2.

Overall diagnostic accuracy using lung ultrasound improved only for the extended training group (clinical 92% vs ultrasound 97%), whereas the focused training group's accuracy was unchanged (clinical 87% vs ultrasound 88%).

ROC analysis demonstrated a superior diagnostic performance of ultrasound when compared to clinical diagnosis (Table 3).

DISCUSSION

In this prospective, observational study of residents performing lung ultrasound of patients with dyspnea, the diagnostic accuracy incorporating ultrasound increased compared to a standard diagnostic approach relying on history, physical exam, blood tests, and radiography. To our knowledge, this is the first study of residents independently performing lung ultrasound with a pocket ultrasound to diagnose dyspnea. Receiver operating curve analysis shows improvements in diagnostic accuracy for causes such as PNA, pleural effusion and COPD/asthma and demonstrates the feasibility and clinical utility of residents using pocket ultrasounds. The finding that improvements in sensitivity and specificity were larger in the extended training group highlights the need for sufficient training to demonstrate increased utility. Although a 2-week critical care ultrasound elective may not be possible for all residents, perhaps training of intensity somewhere in between these 2 levels would be most feasible.

Challenges in diagnosing dyspnea have been well described, attributed to a lack of accurate history combined with often insensitive and nonspecific physical exam findings, blood tests, and radiographs.[8,9] Further, patients often present with multiple

TABLE 1. Patient Characteristics and Diagnostic Data

Age, y, mean	69
Sex, male, %	52.2
BMI, mean, kg/m^2	25.7
Comorbidities, %	
COPD	43.3
CHF	23.9
Hypertension	59.4
Diabetes mellitus	29
Atrial fibrillation	18.9
DVT/PE	1.5
Lung cancer	5.9
Finding on admission, %	
CXR available	94
Chest CT available	22.4
WBC >10.4 K/μL	36.2
BNP >400 pg/mL	27.5
Temperature >100.9°F	6
Heart rate >90 bpm	47.8
Desaturation*	32

NOTE: Abbreviations: BMI, body mass index; BNP, B-type natriuretic peptide; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; CT, computed tomography; CXR, chest x-ray; DVT, deep vein thrombosis; PE, pulmonary embolism; WBC, white blood cell count. *Oxygen saturation <92% or requiring >4 L oxygen.

TABLE 3. Receiver Operating Curve Analysis for All Residents

Diagnosis	CLINDIAG AUC, N = 69	USDIAG AUC, N = 69	P Value
COPD/asthma	0.73	0.85	0.06
Pulmonary edema	0.85	0.89	0.49
Pneumonia	0.77	0.88	0.01
Pleural effusion	0.76	0.96	0.002
Other*	0.78	0.69	0.01
All causes, n = 69	0.81	0.87	0.01

NOTE: Abbreviations: AUC, area under the curve; CLINDIAG, initial clinical diagnosis; COPD, chronic obstructive pulmonary disease; N, number of patients examined; USDIAG, diagnosis incorporating lung ultrasound. *Other diagnoses included anemia, ascites, and dehydration.

TABLE 2. Changes in Sensitivity and Specificity Among Groups Using Lung Ultrasound

	Focused Training Group				Extended Training Group			
	CLINDIAG, N = 27		USDIAG, N = 27		CLINDIAG, N = 61		USDIAG, N = 20	
Diagnosis	Sens, %	Spec, %	Sens, %	Spec, %	Sens, %	Spec, %	Sens, %	Spec, %
COPD/asthma	60	96	60	96	55	96	91	96
Pneumonia	45	90	36	100	93	88	96	100
Pulmonary edema	100	85	100	86	89	96	89	100
Pleural effusion	57	100	86	96	57	96	100	96
Other	50	100	75	96	80	96	80	100

NOTE: Abbreviations: CLINDIAG, initial clinical diagnosis; COPD, chronic obstructive pulmonary disease; N, number of diagnoses; Sens, sensitivity; Spec, specificity; USDIAG, diagnosis incorporating lung ultrasound.

contributing causes as was evidenced in this study.[10] Lack of initial, accurate diagnoses often leads to the provision of multiple, incorrect treatment regimens that may increase mortality.[11] The high accuracy of lung ultrasound in defining causes of respiratory failure suggests potential as a low-cost solution.[12]

This study design differed from prior work in several respects. First, it included patients presenting with dyspnea to a hospital ward rather than acute respiratory failure to an intensive care unit (ICU), suggesting its diagnostic potential in a broader population of patients and settings. Second, the lung ultrasound was integrated with traditional clinical information rather than relied upon alone, a situation mimicking real-world application of POC-US. Third, operators were residents with limited amounts of training rather than highly trained experts. Finally, the lung ultrasound exams were performed using a pocket ultrasound with inferior imaging capability than larger, more established ultrasound devices. Despite these constraints, the utility of lung ultrasound was still evident, particularly in the diagnosis or exclusion of pneumonia and PLEFF.

Limitations include reliance on a small cohort of highly motivated residents with an interest in pulmonary and critical care, 2 who are authors of this article, making reproducibility a concern. Although convenience sampling may more closely mimic real world practices of POC-US, a bias toward less challenging patients is possible and may limit conclusions regarding utility. Over-reading and feedback were not provided to residents to improve their performance of lung ultrasound exams. Also, because chest CT is considered the gold standard in most studies examining the diagnostic accuracy of lung ultrasound, all residents aware of these data may underestimate the potential impact of integrating lung ultrasound with all clinical findings. Finally, the high cost of pocket ultrasounds is a barrier to general use. Recent studies on the significant cost savings associated with POC-US make a further analysis of cost-benefit ratios mandatory before broad use can be recommended.[13]

CONCLUSIONS

Residents participating in lung ultrasound training with a pocket ultrasound device showed improved diagnostic accuracy in their evaluation of patients with dyspnea. Those who received extended training had greater improvements across all causes of dyspnea. Training residents to apply lung ultrasound in non-ICU settings appears to be feasible. Further study with a larger cohort of internal medicine residents and perhaps training duration that lies in between the focused and extended training groups is warranted.

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