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Evaluation of Early Primary Care Implementation of Point of Care Ultrasound in Outcomes of Patients with Dyspnea as Compared to Standard Diagnostic Exams

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Abstract

The purpose of this systematic literature review is to evaluate the applicability of point of care ultrasound (POCUS) in rural primary care. More specifically, the review seeks to evaluate the use of POCUS regarding outcomes in patients with dyspnea. Six of the most common and potentially life-threatening causes of dyspnea were chosen to review. They are asthma, heart failure, chronic obstructive pulmonary disease (COPD), pneumonia, pneumothorax, and pulmonary embolism. In this review, a literature search was performed using the following electronic databases: PubMed, Cochran Review, and Google Scholar. Only articles since 2011 were selected for review with the majority being within the last five years. All except one article is either a peer reviewed randomized control trial or systematic review. The non-peer reviewed article was included as it provides background, entry-level information on the application of point of care ultrasonography in primary care. It also cites peer-reviewed sources for support. Research consistently demonstrates point of care lung ultrasonography as an accurate tool to assist in examining a patient. It is also non-inferior to the respective conventional method of imaging for asthma/chronic obstructive pulmonary disease, heart failure, pneumonia, pneumothorax, and pulmonary embolism. Unfortunately, evidence is lacking in definitively demonstrating that early rural primary care POCUS use improves outcomes. However, a few studies do demonstrate that it has the potential to improve patient outcomes and should be further studied.

Keywords: point of care ultrasound (POCUS), primary care, family practice, dyspnea, pneumonia, congestive heart failure (CHF), pneumothorax, asthma, chronic obstructive pulmonary disease (COPD), emphysema, bronchitis, pulmonary embolism (PE), morbidity, mortality, outcomes

Introduction

Dyspnea, or shortness of breath, is a common medical complaint with a very diverse set of causes and a wide range of severity from self-limiting to life threatening. For example, a viral upper respiratory infection generally only requires symptomatic treatment and usually resolves on its own. However, diseases such as a pneumothorax and pneumonia often require therapy to ensure recovery. The nature of this literature review is to evaluate if early primary care implementation of point of care ultrasound (POCUS) improves outcomes of undifferentiated dyspnea patients as compared to standard diagnostic exams. Six of the most common and potentially life-threatening causes of dyspnea were chosen to review. They are asthma, heart failure, chronic obstructive pulmonary disease (COPD), pneumonia, pneumothorax, and pulmonary embolism. The goal is to arm primary care providers with an accurate and cost-effective device to aid in their diagnosis and treatment of dyspnea.

Statement of the Problem

Primary care facilities often lack the resources like conventional radiography and computed tomography that would generally be used to evaluate patients with dyspnea. Facilities with imaging services may have limited hours or not be within reasonable transportation distance for many rural patients. The stethoscope is a common and helpful tool but has a rather low sensitivity and specificity when diagnosing the cause of dyspnea. This leaves patients with options such as ambulance transport to a hospital emergency department, the clinic provider making an educated differential diagnosis and treatment plan, and/or waiting until imaging services become available. Treatment plans such as these could lead to expensive therapy, incorrect therapy, delayed therapy, and/or worsening of the patient condition.

Research Question

Does early primary care implementation of point of care ultrasound improve outcomes of patients with dyspnea as compared to standard diagnostic exams?

Methods

A literature search was performed using the following electronic databases: PubMed, Cochran Review, and Google Scholar. The keywords included point of care ultrasound (POCUS), primary care, family practice, dyspnea, pneumonia, congestive heart failure (CHF), pneumothorax, asthma, chronic obstructive pulmonary disease (COPD), emphysema, bronchitis, pulmonary embolism (PE), morbidity, mortality, and outcomes. Research was limited to the past 10 years. Randomized controlled trials, peer reviewed journal articles, and systematic reviews were included. Articles were further selected based on relevance, quality, and bias.

Literature Review

Review of the literature indicates that POCUS can assist in differentiating causes of dyspnea and aid in delivery of appropriate therapeutic interventions. Six of the most common and potentially life-threatening causes of dyspnea were chosen to review. They are asthma, heart failure, chronic obstructive pulmonary disease (COPD), pneumonia, pneumothorax, and pulmonary embolism.

Point of Care Lung Ultrasound

Training for various lung exams has been shown to require a relatively small amount of time for yielding improved diagnostic accuracy. For example, two hours of didactic and hands-on training improved diagnostic accuracy of heart failure from 50% to 75% (Bornemann et al., 2018). Three hours of training resulted in a sensitivity of 90%-96% and specificity of 88%-93% for detection of pneumonia.

With the advancements in technology, ultrasound has rapidly become a device that is relatively compact, inexpensive, and diagnostically accurate for many applications. Some of these applications yield more accurate results than the conventional method of imaging. Other benefits include faster diagnosis, reduced number of tests, and decreased patient exposure to ionizing radiation. Additionally, this brings the clinician back to the patient's bedside as they will be performing the exam instead of having various technologists perform their respective imaging modalities. This tool can often be used at the bedside resulting in a better patient examination than physical findings alone. For example, when evaluating pulmonary edema, the traditional exam finding of crackles auscultated through a stethoscope is 19-64% sensitive and 82-94% specific whereas the POCUS findings of B-lines is 94% sensitive and 92% specific (Maw et al., 2020).

In a prospective, randomized trial, six emergency medicine specialists were evenly divided into two groups. Each group then underwent didactic and hands-on training in POCUS or stethoscope use respectively. All patients enrolled were randomly placed into either the POCUS or stethoscope group. While not statistically significant, diagnostic performance of ultrasound was improved over stethoscope in heart failure (90% vs 86%, 1.00 vs 0.89) and pneumonia (90% vs 86.7%, 0.75 vs 0.73) (Özkan et al., 2015). This study is limited by its size but does support that further investigation of ultrasound application is appropriate.

In a literature review, diagnostic performance of ultrasound was improved over chest x-ray in pneumonia with sensitivity 95% vs 77% and specificity 90% vs 91%, in pneumothorax, sensitivity 91% vs 50% and specificity 98% vs 99%, and in pleural effusions, sensitivity 94% vs 51% and specificity 98% vs 91% (Shrestha et al., 2018). Evidence continues to illustrate that

POCUS is at least non-inferior to the traditional imaging techniques for the respective lung pathologies.

Additionally, a randomized-controlled study (Pivetta et al., 2019), assigned 518 patients with indications of acute decompensated heart failure into one of two groups receiving chest x-ray and pro-brain natriuretic peptide or lung ultrasound. They found that lung ultrasound had both superior specificity (84.4% vs 81%) and sensitivity (90.3% vs 88.7%) compared to the criterion standard of diagnosis. Additionally, they had a quicker time to diagnosis of 5 minutes compared to 104.5 minutes.

While ultrasound at the bedside may be a relatively new development, an international committee has come together and graded the strength of ultrasound findings for various lung diseases (Volpicelli et al., 2012). Twenty-eight experts from eight countries reviewed literature between 1966 and 2011 from multiple databases including but not limited to PubMed, Medline, and Embase. Internal and external peer-review of the recommendations took place before publication. Updates will occur every four years or whenever notable changes in evidence appear. While discussing the specific recommendations is beyond the scope of this literature review, there is value in realizing world experts have determined that POCUS is of such value that they have drafted specific guidelines on its use for various lung pathologies.

In a prospective, observational study performed in an emergency department, patients with dyspnea were evaluated for consensus between lung ultrasonography and chest radiography. Lung ultrasonography and chest radiography were both performed in 404 patients. Computed Tomography (CT) scans were performed in 118 patients when chest radiography and lung ultrasound gave discordant results. Ultrasound interpretation was completed by the clinician during the scan. However, for chest radiography, the average time between the order and its final

interpretation was 1 hour and 35 minutes. Ultrasonography and chest radiography exhibited high concordance in most pulmonary diseases, especially in pulmonary edema ($\kappa = 95\%$) (Zanobetti et al., 2011). For lung abnormalities such as free pleural effusion, loculated pleural effusion, pneumothorax, and lung consolidation, the concordance was similar for both left- and right-side lungs (all p not significant). CT scans confirmed the ultrasound findings in 63% of patients ($p < .0001$) when ultrasonography and chest radiography gave discordant results. Interestingly, ultrasound yielded greater sensitivity than chest radiography in patients with free pleural effusion ($p < .0001$).

POCUS in Asthma and COPD

A prospective, blinded study with 57 patients in an urban hospital system evaluated the impact of a three-part POCUS exam composed of abbreviated echocardiography, lung ultrasound, and inferior vena cava collapsibility on the treating physician's immediate diagnostic impression. The patient's history and physical was taken and then a most likely diagnosis was prescribed prior to diagnostic testing. The triple scan was then performed by the sonography investigators, they disclosed their results, and then the most likely diagnosis was re-evaluated. The final diagnosis was made by medical record review, but reviewers were blinded to the triple scan results. The different diagnoses were then compared.

Diagnostic accuracy improved from 53% before triple scan to 77% after triple scan ($p = .003$) (Mantuani et al., 2016). The treating physician's primary impression changed after triple scan in 27 of 57 (47.3%) cases. In 17 of 57 (29.8%) cases, an initial incorrect diagnosis was changed to the correct diagnosis after the triple scan. However, in three of 57 (5.2%) cases the opposite occurred where the treating physician changed a correct initial diagnosis to an incorrect diagnosis. The final diagnoses being acute decompensated heart failure (26%), COPD/asthma

(30%), and pneumonia (28%). Overall accuracy of the treating physician's diagnosis increased from 53% before triple scan to 77% after triple scan (p=0.003). Based on a five-level Likert scale, the treating physician's confidence in their clinical impressions improved significantly from a median score of three before the triple scan to five after the triple scan (p = .017). This has great clinical impact when providers are forced to make clinical decisions and initiate treatments when they may not have all of the information, such a laboratory values. These triple scan exams generally took less than two minutes to complete.

A literature review of 25 studies from but not limited to PubMed, Embase, and Scopus determined that in patients with acute dyspnea or respiratory failure, lung ultrasonography demonstrated predominance of A-lines with lung sliding without posterior-lateral alveolar pleural syndrome had a sensitivity of 0.78 (95% CI [0.67, 0.86]) and specificity of 0.94 (95% CI [0.89, 0.97]) for exacerbations of COPD/asthma (Staub et al., 2019).

POCUS in Heart Failure

A prospective study was performed in Slovenia comparing a heart failure group of 129 patients and an asthma/COPD group of 89 patients. All patients underwent lung ultrasound examinations, basic laboratory testing, rapid NT-proBNP testing, and chest X-rays. Clinicians would make their initial diagnosis based on their assessment and point of care lung ultrasound exam. They were blinded to the NT-proBNP results. A review of the medical records was performed to determine final diagnosis.

Ultrasound B-lines findings had 100% sensitivity, 95% specificity, 100% negative predictive value, and 96% positive predictive value for the diagnosis of heart failure (Prosen et al., 2011). NT-proBNP (cutoff point 1,000 pg/mL) had 92% sensitivity, 89% specificity, 86% negative predictive value, and 90% positive predictive value. The Boston modified criteria had

85% sensitivity, 86% specificity, 80% negative predictive value, and 90% positive predictive value. Significant differences were found between ultrasound B-lines and NT-proBNP ($p < .05$) and Boston modified criteria ($p < .05$). The combination of B-lines and NT-proBNP had 100% sensitivity, 100% specificity, 100% negative predictive value, and 100% positive predictive value. Interestingly, they were able to exclude heart failure in patients with pulmonary-related dyspnea who had a positive NT-proBNP (> 1,000 pg/mL) and a prior history of heart failure. This can prove useful when patients have multiple comorbidities and the clinician is trying to determine the active disease component.

A literature review of 25 studies from but not limited to PubMed, Embase, and Scopus determined that in patients with acute dyspnea, lung ultrasonography demonstrated modified diffuse interstitial syndrome (scans with three or more B-lines in at least two chest areas bilaterally) had a sensitivity of 0.90 (95% CI [0.87, 0.93]) and specificity of 0.93 (95% [CI 0.91, 0.95]) for acute heart failure, whereas B-profile (predominance of B-lines in anterior thoracic regions and lung sliding present) had a sensitivity of 0.93 (95% CI [0.72, 0.98]) and specificity of 0.92 (95% CI [0.79, 0.97]) for acute heart failure (Staub et al., 2019).

POCUS in Pneumonia

In a literature review of 10 studies, pooled sensitivity and specificity for the diagnosis of pneumonia using lung ultrasound were 94% (95% CI [92%, 96%]) and 96% (95% CI [94%, 97%]) with positive and negative likelihood ratios of 16.8 (7.7-37.0) and 0.07 (0.05-0.10) (Chavez et al., 2014).

A prospective observational study enrolled children aged 1 month to 18 years in an Australian pediatric emergency department who had a chest radiograph ordered for suspicion of pneumonia (Lissaman et al., 2019). Lung ultrasounds evaluated pneumonia as defined by lung

consolidation with air bronchograms. Radiograph and ultrasound results both required agreement between two readers. In cases of discordance, final results were determined by another evaluator. Patient management was decided by treating clinicians who were blinded to lung ultrasound results. Out of 97 patients, chest radiography was positive for pneumonia in 44/97 (45%) and lung ultrasound was positive in 57/97 (59%). Ultrasound sensitivity was 91% (95% CI [78%, 98%]) and specificity was 68% (95% CI [54%, 80%]).

Three hundred sixty-two patients with suspected community acquired pneumonia were enrolled in 14 European centers for a prospective, multi-center study (Reissig et al., 2012). Clinicians performed a history, clinical examination, laboratory testing, and lung ultrasound. Then a chest radiograph in two planes was performed. Sonographers were blinded to the chest radiograph. A low-dose CT scan was also performed in cases of inconclusive or negative radiographic but positive lung ultrasound findings.

Community acquired pneumonia was confirmed in 229 patients (63.3%) (Reissig et al., 2012). Lung ultrasound revealed a sensitivity of 93.4% (95% CI [89.2%, 96.3%]), specificity of 97.7% (95% CI [93.4%, 99.6%]), positive likelihood ratio of 40.5 (95% CI [13.2,123.9]) and 0.07 (95% CI [0.04, 0.11]) for negative likelihood ratio. A combination of auscultation and lung ultrasound increased the positive likelihood ratio to 42.9 (95% CI [10.8, 170.0]) and decreased the negative likelihood ratio to 0.04 (95% CI [0.02, 0.09]).

A literature review of 25 studies from but not limited to PubMed, Embase, and Scopus determined that in patients with acute dyspnea, lung ultrasonography demonstrated consolidation had a sensitivity of 0.82 (95% CI [0.74, 0.88]) and specificity of 0.94 (95% CI [0.85, 0.98]) for pneumonia (Staub et al., 2019).

POCUS in Pneumothorax

In a prospective, observational study of 128 patients presenting with chest pain and shortness of breath to an emergency department in Massachusetts, treating physicians selected diagnoses from a predefined list of possible diagnoses (Buhumaid et al., 2019). Providers ordered all the necessary tests and performed the bedside lung ultrasound without knowledge of test results. They were then made aware of all the results. The final diagnosis was made from a chart review as the reference standard for the diagnosis.

Excluding pneumonia, POCUS had an equal or higher specificity as compared to chest x-ray for all indications in which it was used. The sensitivity and specificity of chest x-ray and POCUS were 38% (95% [CI 13%, 70%]) and 96% (95% CI [90%, 99%]) versus 89% (95% CI [54%, 100%]) and 74% (95% CI [64%, 82%]) respectively (Buhumaid et al., 2019). Point of care ultrasound correctly identified all patients with pneumothorax, pleural effusion, and pericardial effusion. In patients with a normal thoracic ultrasound, chest x-ray did not provide any actionable clinical information. Adding POCUS to the initial evaluation caused a significant narrowing of the median number of differential diagnoses from 5 (IQR 3–6) to 3 (IQR 2–4) ($p < .001$).

POCUS in Pulmonary Embolism

In a prospective, observational study of 199 patients undergoing CT angiography in an emergency department for evaluation of pulmonary embolism, patients received a focused cardiac ultrasound looking for right heart strain (McConnell's sign, septal flattening, right ventricular enlargement, or tricuspid annular plane systolic excursion < 17 mm) and a compression ultrasound looking for deep vein thrombosis (Dwyer et al., 2018). When obtaining the ultrasounds, they were blinded to the CT angiogram results. The ultrasounds were

independently interpreted by both the provider performing the ultrasound and the principal investigator. The principal investigator was also blinded.

Of the patients enrolled in the study, 46/199 (23.1%) were positive for a pulmonary embolism (Dwyer et al., 2018). Of these, 20/46 (43.5%) pulmonary embolisms were located centrally. Of those with a pulmonary embolism, 20/46 (43.5%) had an associated deep vein thrombosis identified on bedside ultrasound. Among patients with a proximal pulmonary embolism, 18/20 (90.0%) had evidence of right heart strain. The combination of lower extremity compression ultrasound and focused cardiac ultrasound was 100% sensitive. Diagnostic accuracy of ultrasound was much lower for peripherally located pulmonary embolisms at 46%.

Outcomes Based on Timely and Accurate Diagnosis

In a literature review, three randomized control trials reported no statistically significant differences for in-hospital mortality. Overall, 5.1% (33 of 634) of participants who had POCUS plus the standard diagnostic pathway died (Gartlehner et al., 2021). The groups that received a standard diagnostic pathway only had a mortality of 6.6% (42 of 641). A random-effects meta-analysis yielded a relative risk of 0.78 (95% CI [0.12, 5.09]). Additionally, in two large, randomized control trials, reported median length of hospital stay was 2.9 days for patients who received POCUS plus the standard diagnostic pathway versus 3.1 days for those who received the standard diagnostic pathway only. This was not a statistically significant result. However, these were in hospital studies, so further evaluation in an out of hospital clinic setting would be appropriate.

In 2020, Golan et al. conducted a randomized, controlled trial to evaluate the effect of a POCUS exam on medical patients' management and clinical outcomes. In this study, 60 patients with chest pain or dyspnea were randomly assigned to a POCUS group or a control group.

POCUS assessment was conducted for the intervention group within 24 hours of internal medicine admission. The POCUS exam revealed clinically relevant findings among 79% of patients and led to alteration of the primary diagnosis among 28% of patients (Golan et al., 2020). Time to appropriate treatment was significantly shorter among patients in the POCUS group compared to the control group with a median time of 5 hours (95% CI [0.5, 9]) vs. 24 hours (95% CI [19, 29] ($p = .014$). The time needed to achieve correct diagnosis by the primary team was shorter in the POCUS group compared to the control group. However, it did not reach statistical significance with a median time of 24 hours (95% CI [18, 30]) vs. 48 hours (95% CI [20–76]) ($p = .12$). Additionally, a higher percentage of patients received timely appropriate treatment in the POCUS group compared to the control group (83.3% vs. 63.3%) but this was also not statistically significant ($p = .08$).

In a prospective, randomized multicenter trial in Danish emergency departments, 211 patients with signs of respiratory failure were randomly assigned to an intervention or control group. Patients received a standard exam and a POCUS exam within four hours of admission. The emergency physician announced his primary presumptive diagnosis and then the ultrasound results were unblinded for the treating emergency physician in the intervention group. Final diagnoses and treatment were determined by blinded review of the medical record by two reviewers after the patient's discharge. Discrepancies were resolved by a third reviewer.

At four hours, there was no change in the proportion of patients with presumptive diagnoses in agreement with final diagnoses with the intervention group at 79.25% (95% CI [70.3, 86.0]) and control group at 77.1% (95% CI [68.0, 84.3]) (Riishede et al., 2021). Interestingly, an increased proportion of appropriate treatment prescribed was noted with intervention group at 79.3% (95% CI [70.3, 86.0]) and the control group at 65.7% (95% CI

[56.0, 74.3]). Also, more patients spent less than one day in hospital in the intervention group at $n = 42$ (39.6%) (95% CI [25.8, 38.4]) vs the control group at $n = 25$ (23.8%) (95% CI [16.5, 33.0). This study does suggest a statistically significant decrease in hospital length of stay.

In a prospective, observational study of 100 patients presenting with dyspnea in an emergency department in Rwanda, the primary treating team performed a traditional history and physical exam, listed their three main diagnoses, and then ranked their confidence accuracy in the leading diagnosis on a Likert scale. Multi-organ POCUS scans were performed by a different physician assessing the heart, lungs, inferior vena cava, lower extremities for deep vein thrombosis, or features of disseminated tuberculosis. The physician then listed their three main diagnoses post-ultrasound and ranked their confidence accuracy in the leading diagnosis on a Likert scale. The hospital diagnosis at discharge was used as the standard in determining the accuracy of the pre- and post-ultrasound diagnoses.

The most frequent discharge diagnoses were acute decompensated heart failure (26.3%) and pneumonia (21.2%) (Umuhire et al., 2019). Ultrasound changed the leading diagnosis in 66% of cases. The diagnostic accuracy for acute decompensated heart failure increased from 53.8% to 100% ($p = 0.0004$) and pneumonia from 38% to 85.7% ($p = 0.0015$). This is important in excluding tuberculosis as a potential cause since it is common in the region. The overall physician diagnostic accuracy increased from 34.7% to 88.8% (Umuhire et al., 2019). The clinician confidence in the leading diagnosis changed from a mean of 3.5 to a mean of 4.7 ($p < .001$).

A prospective, observational, controlled study of 165 patients was conducted at a university hospital. Two teams alternated every other day in managing admitted patients developing acute respiratory and/or circulatory failure. One of the teams used a handheld

ultrasound device in addition to their standard medical exam. The other team only performed standard examination and diagnostic studies. Following their exam, each group selected a diagnosis from a predefined list. Definitive diagnosis was made upon a retrospective review of the patient's medical record.

Correct immediate diagnosis was 94% in the POCUS group and 80% in the control group ($p = .009$) (Zieleskiewicz et al., 2021). The average time to first treatment/intervention was shorter in the POCUS group at 15 minutes (95% CI [10, 25]) vs. 34 minutes (95% CI [15, 40]) ($p < .001$). Patients admitted to the ICU had a median length of stay of 3 days [IQR 2–7] for the POCUS group and 5 days [IQR 3–10] in the control group ($p = 0.01$). The median hospital length of stay did not differ between the POCUS group at 16 days [IQR 9–25] and the control group at 16 days [IQR 9–28] ($p = .44$). ICU mortality rates were 11% in the POCUS group and 25% in the control group ($p = .04$). In-hospital mortality rates were 17% in the POCUS group and 35% in the control group ($p = .007$). However, this was not supported in the propensity score sample ($p = .79$ and $p = .53$, respectively).

Discussion

This literature review indicates that POCUS requires minimal time for proficiency, is non-inferior, and costs less than conventional imaging methods for the respected disease. However, few studies exist evaluating its use in the primary care setting. Also, few studies have evaluated patient outcomes utilizing POCUS as compared to traditional methods. Those that have, fail to definitively illustrate a statistically significant improvement in morbidity and/or mortality. Fortunately, research shows that the various lung exams can be taught and learned in several hours. Pairing the ease of learning lung exams, size and portability, frequency required to maintain proficiency, and lack of ionizing radiation makes this exam technique a reasonable

choice for primary care providers. It is reasonable to say that point of care ultrasonography can aid in an accurate and more prompt diagnosis of dyspnea. It is also reasonable to say that earlier treatment of dyspnea potentially reduces patient morbidity and/or mortality. Further research is required to determine if POCUS in the primary care setting in fact improves patient morbidity and mortality.

Applicability to Clinical Practice

Through the discussed information, medical providers will be able to better understand the benefits and limitations of POCUS exams as they apply to the patient with undifferentiated dyspnea. Appropriate application of point of care lung ultrasonography can help decrease health care costs, aid in determining the most appropriate treatment plan, and potentially improve patient outcomes.

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