Original Contribution

Can emergency physicians diagnose and correctly classify diastolic dysfunction using bedside echocardiography?☆,☆☆

Robert R. Ehrman, MD [a,*], Frances M. Russell, MD [b,f], Asimul H. Ansari, MD [c], Bosko Margeta, MD [d], Julie M. Clary, MD [e], Errick Christian [b], Karen S. Cosby, MD [b], John Bailitz, MD [b]

[a] Department of Emergency Medicine, Wayne State University School of Medicine, 4201 St Antoine, Suite 3R, Detroit, MI 48201
[b] Department of Emergency Medicine, The John H. Stroger, Jr. Hospital of Cook County, Rush University School of Medicine, 1969 W Ogden Ave, Chicago, IL, 60612
[c] Department of Medicine, Division of Cardiology, Northwestern University Feinberg School of Medicine, 676 N St Clair St, Chicago, IL 60611
[d] Department of Medicine, Division of Cardiology, The John H. Stroger, Jr. Hospital of Cook County, Rush University School of Medicine 1969 W Ogden Ave, Chicago, IL, 60612
[e] Department of Medicine, Division of Cardiology, Indiana University School of Medicine, 545 Barnhill Dr EH 317, Indianapolis, IN 46202
[f] Department of Emergency Medicine Indiana University School of Medicine 1701 N. Senate Blvd, B401 Indianapolis, IN 46202

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ABSTRACT

Objectives: The goal of this study was to determine if emergency physicians (EPs) can correctly perform a bedside diastology examination (DE) and correctly grade the level of diastolic function with minimal additional training in echocardiography beyond what is learned in residency. We hypothesize that EPs will be accurate at detecting and grading diastolic dysfunction (DD) when compared to a criterion standard interpretation by a cardiologist.
Methods: We conducted a prospective, observational study on a convenience sample of adult patients who presented to an urban emergency department with a chief concern of dyspnea. All patients had a bedside echocardiogram, including a DE, performed by an EP-sonographer who had 3 hours of didactic and hands-on echocardiography training with a cardiologist. The DE was interpreted as normal, grade 1 to 3 if DD was present, or indeterminate, all based on predefined criteria. This interpretation was compared to that of a cardiologist who was blinded to the EPs' interpretations.
Results: We enrolled 62 patients; 52% had DD. Using the cardiology interpretation as the criterion standard, the sensitivity and specificity of the EP-performed DE to identify clinically significant diastolic function were 92% (95% confidence interval [CI], 60-100) and 69% (95% CI, 50-83), respectively. Agreement between EPs and cardiology on grade of DD was assessed using κ and weighted κ: $\kappa = 0.44$ (95% CI, 0.29-0.59) and weighted $\kappa = 0.52$ (95% CI, 0.38-0.67). Overall, EPs rated 27% of DEs as indeterminate, compared with only 15% by cardiology. For DEs where both EPs and cardiology attempted an interpretation (indeterminates excluded) $\kappa = 0.45$ (95% CI, 0.26 to 0.65) and weighted $\kappa = 0.54$ (95% CI, 0.36-0.72).
Conclusion: After limited diastology-specific training, EPs are able to accurately identify clinically significant DD. However, correct grading of DD, when compared to a cardiologist, was only moderate, at best. Our results suggest that further training is necessary for EPs to achieve expertise in grading DD.

1. Introduction

Congestive heart failure (CHF) affects approximately 5.7 million people in the United States and was a contributing cause in more than 280,000 deaths in 2008 [1]. Currently, CHF costs the United States $34.4 billion per year in health care costs, medications, and lost productivity [2]. The prevalence of CHF is projected to rise, making this condition of even greater concern for health care in the United States [3].

Diastolic heart failure (DHF) is defined as heart failure with normal (or near-normal) left ventricular ejection fraction, in the absence of other explanatory conditions such as valvular lesions. This condition is also known as *heart failure with preserved ejection fraction* and accounts for approximately half of all patients with clinical heart failure [4,5]. Recent evidence suggests that the prevalence of DHF is increasing, as is the mortality rate of patients with this condition [6]. In patients with known systolic heart failure, the presence of underlying diastolic dysfunction (DD) predicts a worse prognosis [7]. In addition, DD is an independent predictor of adverse outcomes such as in-hospital mortality, increased rate of readmission, and failure of extubation [8–13].

Given the prevalence of this disease, patients with DHF will present to the emergency department (ED) and may benefit from early recognition of this as the etiology of their symptoms. Diastolic dysfunction, alone or in combination with systolic dysfunction, not only has a worse prognosis but may also require alternative treatment strategies,

especially in patients with more severe diastolic abnormalities [8,11]. For these reasons, rapid identification of these abnormalities has the potential to benefit a subset of dyspneic ED patients.

To our knowledge, only one prior study has assessed emergency physician's (EP's) ability to diagnose DD. This study, published by Ünlüer et al [14], found that the sensitivity and specificity for diagnosis of DD were 89% and 80%, respectively. However, they did not attempt to grade the level of DD. In addition, their diastology examination (DE) did not use tissue Doppler imaging (TDI), which has been previously recommended by the American Society for Echocardiography [15].

The goal of this study was to determine if EPs can correctly perform a bedside DE and properly grade the level of diastolic function after minimal additional training in echocardiography. We hypothesize that EPs will be accurate at detecting and grading DD when compared to a criterion standard interpretation by a cardiologist.

2. Methods

2.1. Study design and setting

This was a prospective, observational study that compared EP's ability to identify and grade diastolic cardiac function to that of a cardiologist board certified in echocardiography. This study was conducted at an urban tertiary-care teaching hospital with more than 120,000 annual ED visits and was approved by the Institutional Review Board.

2.2. Study population

We enrolled a convenience sample of patients who presented to the ED and met the following inclusion criteria: age at least 18 years, a chief concern of dyspnea, and at least 2 potential etiologies for the dyspnea in the treating clinician's differential diagnosis. Exclusion criteria included an electrocardiogram showing an ST segment elevation myocardial infarction, treatment for acute CHF (eg, diuretics, nitroglycerin, noninvasive positive pressure ventilation) more than 30 minutes before enrollment, treating clinician confidence in diagnosis (ie, history, physical examination, and clinical course consistent with a single known underlying problem), refusal of consent, enrollment in the study at a prior ED visit, pregnancy, and incarceration.

Eligible patients were identified by both physicians and research assistants using a standardized screening process. Screening took place when EP-sonographers were available to perform a DE, generally Monday through Friday from 9:00 AM to 5:00 PM. All participants were consented before enrollment. Family members provided consent for patients unable to consent themselves.

2.3. Intervention and data collection

Each patient had a bedside echocardiogram performed by an EP-sonographer (RE, FR). Both EP-sonographers had previous ultrasonography (US) experience before participation in the study, each having performed more than 1000 US examinations, including echocardiograms.

Before commencement of the study, each sonographer received 3 hours of didactic instruction from a cardiologist covering the principles of normal and abnormal diastolic cardiac function, US methods for assessing and interpreting diastolic cardiac function, and technical aspects of performing a DE. Didactic sessions also included hands-on scanning time with a cardiologist. In addition, each sonographer spent 3 hours in the echocardiography reading room interpreting DEs under the direction of a cardiologist board certified in echocardiography. As a final step before enrolling patients, each sonographer performed and interpreted 5 DEs that were reviewed and critiqued by the study cardiologist.

Sonographers were blinded to patients' medical history and results of any laboratory or imaging tests obtained during the index visit.

2.4. DE protocol

All echocardiograms were performed with a Mindray M7 (Mindray Corp, Shenzhen, China) ultrasound machine using a phased-array 2- 4-MHz transducer. Patients were placed in a position of comfort; when possible, this was semirecumbent with head-of-bed elevation between 30° and 45°. A left lateral decubitus position was used in select patients to improve image quality provided that this did not cause discomfort.

The DE was performed as part of a 3-view echocardiogram that also included assessment for presence or absence of pericardial effusion, gross estimation of ejection fraction, gross estimation of Right ventricle:Left ventricle (RV:LV) chamber size, and diameter and collapsibility of the Inferior vena cava (IVC) [16]. Diastology examination parameters were obtained from the apical 4-chamber view and included the following:

1. Peak transmitral inflow velocity in early (E) and late (A) diastole using pulsed-wave Doppler
2. Septal and lateral mitral annular excursion velocity (E'$_{sept}$ and E'$_{lat}$, respectively) in early diastole using TDI.

2.5. Grading diastolic function

A simplified method for grading diastolic function was developed using the American Society for Echocardiography guidelines [15] in conjunction with the study cardiologist using the peak E velocity; peak A velocity; and the lateral, septal, and average mitral annular excursion velocities (E'$_{avg}$):

- Normal: E'$_{sept}$ ≥ 8 *and* E'$_{lat}$ ≥ 10
- Grade 1: E'$_{sept}$ < 8 or E'$_{lat}$ < 10 *and* E/E'$_{avg}$ < 8 or E/A < 0.8
- Grade 2: E'$_{sept}$ < 8 or E'$_{lat}$ < 10 *and* E/E'$_{avg}$ 8-12 or E/A 0.8-1.5
- Grade 3: E'$_{sept}$ < 8 or E'$_{lat}$ < 10 *and* E/E'$_{avg}$ > 12 or E/A > 1.5
- Indeterminate (if any of the following conditions were met): heart rate > 100 beats per minute, fusion of E and A waves, presence of pericardial effusion, atrial or ventricular dysrhythmias (other than isolated PACs or PVCs), immobile mitral valve leaflets.

All measurements were made on the spectral Doppler tracings, and calculations were performed by the US machine's cardiology software package. The amount of time required to perform the DE (only parameters unique to the DE not normally acquired during EP echocardiograms) was recorded. A standardized data collection form was used to record all findings of the echocardiogram.

Grade 2 and grade 3 DD were considered clinically significant because both are associated with elevated left ventricular filling pressures and thus are potential causes of dyspnea. Grade 1 DD is generally asymptomatic because left ventricular filling pressure is normal [15].

2.6. Outcome measures

The criterion standard for presence and grade of DD was interpretation of EP-performed echocardiograms by a single cardiologist board certified in echocardiography. The cardiologist was asked to use the same criteria for assessing diastolic function as were used by EPs, and was blinded to all patient information and the EP-sonographers' interpretations.

The primary outcome measure was agreement between EPs and cardiology on classification of diastolic function. This was assessed using κ and linear-weighted κ.

2.7. Statistical analysis

We enrolled 20 dyspneic patients in a pilot study in order to estimate the prevalence of DD in our ED population. All patients in the pilot study had a bedside DE performed by an EP who rated diastolic function as "normal" or "abnormal." Cases rated as "abnormal" by EPs were then reviewed by the study cardiologist who confirmed or refuted this interpretation. Analysis of the pilot data showed a prevalence of DD of approximately 40%.

We calculated that we would need a sample size of 50 patients to allow determination of a statistically significant ($P \leq .05$) κ, assuming at least 30% prevalence of positive findings (ie, abnormal examinations), with 80% power to detect a κ of 0.4 using a one-tailed test where the null hypothesis states that κ is zero. Interrater reliability between EP-sonographers and cardiologists was also assessed using κ and linear-weighted κ. In addition, sensitivity, specificity, positive likelihood ratio, and negative likelihood ratio for the EP-performed DE were calculated and 95% confidence intervals (CIs) were derived using SPSS Statistics for Windows (Version 21.0; IBM Corp, Armonk, NY).

3. Results

3.1. Patient characteristics

We enrolled 70 patients between December 2012 and July 2013 and had complete data on 62 patients. Eight patients were excluded: 1 patient withdrew consent before completion of the US, and 7 patients lacked adequate US windows to obtain the images necessary to assess diastolic function. Demographic information on the patients who completed the study is listed in Table 1.

3.2. Technical aspects of DEs

Cardiology found the images for all 62 cases to be technically adequate to assess diastolic function. Emergency physicians rated diastolic function as normal in 8 (13%) of 62 patients compared with 21 (34%) of 62 by cardiology. Abnormal diastolic function was found in 36 (58%) of 62 and 32 (52%) of 62 by EPs and cardiology, respectively. Of the 62 examinations, EPs rated 27% as having indeterminate diastolic function (n = 17) compared with only 15% (n = 9) by cardiology. These results are summarized in Table 2.

Table 1
Patient characteristics

	Total
	N = 62
Age, SD, range	56 ± 14, 22-91
Male	30 (48.4)
Medical comorbidities	
Congestive heart failure	19 (30.6)
COPD	25 (40.3)
Coronary artery disease	11 (17.7)
Hypertension	40 (64.5)
Lung cancer	6 (9.7)
Diabetes	19 (30.6)
Smoking	11 (17.7)
Vital signs on arrival	
Hypotension (SBP < 100)	3 (4.8)
Tachycardia (HR > 100)	25 (40.3)
Tachypnea (RR > 20)	23 (37.1)
Fever (>100.4°F)	0 (0)
Hypoxia (<92%)	6 (9.7)
Disposition	
Home	10 (16.1)
Floor	41 (66.1)
Observation unit	4 (6.5)
ICU	7 (11.3)
Final discharge diagnosis	
ADHF	20 (32.3)
COPD	12 (19.4)
Pneumonia	10(1.6)
Lung cancer	4 (6.5)
Noncardiogenic pulmonary edema	1 (1.6)
Acute coronary syndrome	1 (1.6)
Other	23 (37.1)

Values are mean ± standard deviation, number (percentage). Abbreviations: ADHF = acutely decompensated heart failure; COPD = chronic obstructive pulmonary disease; HR = heart rate; ICU = intensive care unit; RR = respiratory rate; SBP = systolic blood pressure.

Table 2
Comparison of EP and cardiology interpretation of DEs

	DE (EP): NL	DE (EP): Grd 1	DE (EP): Grd 2	DE (EP): Grd 3	DE (EP): Indt	Total
DE (C): NL	8	4	4	1	4	21
DE (C): Grd 1	0	10	5	0	1	16
DE (C): Grd 2	0	1	3	3	3	10
DE (C): Grd 3	0	0	0	5	1	6
DE (C): Indt	0	0	0	1	8	9
Total	8	15	11	10	18	62

Numbers in green represent agreement between raters; those in red represent disagreement. Abbreviations: C = study cardiologist; Grd = grade; Indt = indeterminate.

3.3. Comparison of EP to cardiologist interpretation of DEs

Interpretation of the DE was performed on 44 patients by both EPs and cardiology (this excludes any patients with indeterminate diastolic function). Using the cardiologist's interpretation as the criterion standard, the sensitivity, specificity, positive likelihood ratio, and negative likelihood ratio for the EP-performed DE to detect abnormal diastolic function were as follows: 100% (95% CI, 84-100), 47% (95% CI, 24-71), 1.89 (95% CI, 1.21-2.96), and 0.0 (95% CI, 0-⁻∞), respectively. Accuracy of the EP-performed DE was 79% (95% CI, 65-77).

For all DEs performed, agreement between EPs and cardiology was κ = 0.44 (95% CI, 0.29-0.59) and weighted κ = 0.52 (95% CI, 0.38-0.67). For DEs in which both EPs and cardiology attempted an interpretation (ie, patients with indeterminate diastolic function [n = 18] were excluded), κ = 0.45 (95% CI, 0.26-0.65) and weighted κ = 0.54 (95% CI, 0.36-0.72).

Results of the DE were also dichotomized to normal/grade 1 vs clinically significant (grade 2/grade 3) DD. Again, using the cardiologist's interpretation as the criterion standard, the sensitivity, specificity, positive likelihood ratio, and negative likelihood ratio for the dichotomized outcome were as follows: 92% (95% CI, 60-100), 69% (95% CI, 50-83), 2.93 (95% CI, 1.71-5.04), and 0.12 (95% CI, 0.02-0.81), respectively.

3.4. Comparison of EP and cardiology interpretations to comprehensive inpatient echocardiograms

A total of 24 patients had a comprehensive echocardiogram performed while hospitalized during the index visit. Of these 24, 7 had normal diastolic function (29%), 12 had abnormal diastolic function (50%), and 5 were indeterminate (21%), as per the final echocardiogram report. Agreement between EPs and comprehensive echocardiogram results showed κ = 0.33 (95% CI, 0.08-0.57) and weighted κ = 0.39 (95% CI, 0.14-0.64) for all DEs. When indeterminates were excluded, κ = 0.35 (95% CI, 0.005-0.69) and weighted κ = 0.47 (95% CI, 0.17-0.77). Agreement between the study cardiologist and the comprehensive echocardiogram results without indeterminates was κ = 0.41 (95% CI, 0.16-0.67) and weighted κ = 0.50 (95% CI, 0.23-0.77). With indeterminates included, κ = 0.34 (95% CI, 0.03-0.65) and weighted κ = 0.41 (95% CI, 0.07-0.74). A summary of κ values is listed in Table 3.

Table 3
Summary of κ values for individual rater pairs

	κ (95% CI)	Weighted κ (95% CI)
EP/C1 (all)	0.44 (0.29-0.59)	0.52 (0.38-0.67)
EP/C1 (Indt excl.)	0.45 (0.26-0.65)	0.54 (0.36-0.72)
EP/F (all)	0.33 (0.08-0.57)	0.39 (0.14-0.64)
EP/F (Indt excl.)	0.35 (0.005-0.69)	0.47 (0.17-0.77)
C1/F (all)	0.41 (0.16-0.67)	0.50 (0.23-0.77)
C1/F (Indt excl.)	0.34 (0.03-0.65)	0.41 (0.07-0.74)
EP/EP	0.66 (0.39-0.92)	0.77 (0.56-0.96)

Abbreviations: C1 = study cardiologist; EP/EP = interrater reliability for EP-sonographers; F = formal (comprehensive) echocardiography report; Indt excl. = indeterminates excluded.

3.5. Interrater reliability for EP interpretations

Interrater reliability for EP-sonographers was assessed by randomly selecting 30 cases for independent and blinded interpretation. There was 95% agreement between EPs for both normal vs abnormal diastolic function and identification of clinically significant DD. For grade of DD, $\kappa = 0.66$ (95% CI, 0.39-0.92) and weighted $\kappa = 0.77$ (95% CI, 0.56-0.96). The average time needed to complete a DE was 5 ± 3 minutes, with a range of 1.5 to 18 minutes.

3.6. Interrater reliability for cardiology interpretations

To assess for interobserver variability between cardiologists, EP-performed echocardiograms were blindly interpreted by 2 additional cardiologists—one from the same institution as the primary cardiologist and one from a different institution: "C2" and "C3," respectively. Agreement was assessed using linear-weighted κ on studies where both raters provided an interpretation (ie, indeterminates excluded). Agreement between the primary cardiologist (C1) and C2 (n = 29) was weighted $\kappa = 0.31$ (95% CI, 0.11-0.51). Agreement between C1 and C3 (n = 28) was weighted $\kappa = 0.33$ (95% CI, 0.09-0.55). Agreement between C2 and C3 (n = 24) was weighted $\kappa = 0.60$ (95% CI, 0.32-0.88). These results are summarized in Table 4.

4. Discussion

The use of bedside ultrasound by EPs has increased dramatically in the last decade. Numerous past studies have shown that EPs can accurately diagnose a wide variety of pathology using this modality [17–20]. Dyspnea is a common presenting concern in the ED, and identifying the cause is often challenging. Diastolic heart failure has a high prevalence [1,6], and numerous studies indicate that delay in diagnosis can lead to increased morbidity and mortality [6,21].

The results of our study show that EPs with limited focused training in diastology can identify DD with a very high sensitivity. A false-positive rate of 20% indicates that EP-sonographers in our study had a tendency to overdiagnose this condition. However, the goal of an EP-performed DE is not to obviate the need for a comprehensive echocardiogram but rather to serve as a tool for rapid assessment of a possible etiology of dyspnea in acutely ill patients. Because the EP-performed DE is, in some ways, a screening examination, sensitivity—which our results demonstrate is excellent—is of more importance than specificity. In addition, when the results of the DE were dichotomized to reflect clinically significant DD, EPs were able to accurately identify patients in whom DD was not a likely contributor to their dyspnea. The sensitivity and specificity of the EP-performed examination to identify clinically significant DD were 92% and 69%, respectively, giving a negative likelihood ratio of 0.12. Thus, identification of normal diastolic function or grade 1 DD indicates that EPs may eliminate DD as a likely cause of their patient's symptoms.

Furthermore, because there is a large discrepancy in the number of examinations recommended by different organizations as necessary to attain proficiency in a single application—from 25 to 300 [22,23]—our results could be due to the relatively small number of DEs performed by each EP-sonographer—approximately 31. In addition, a study by Jang et al [24] found that EP performance in interpretation of beside sonograms improved markedly after 40 examinations. Thus, it is possible that with continued practice, specificity and accuracy of EP-performed DEs would increase.

An EP-performed DE may help identify patients with undiagnosed DD. This would be particularly important for patients in the early stage of disease who may exhibit only minimal symptoms and tend to have normal brain natriuretic peptide (BNP) levels [21]. In these patients, a screening bedside echocardiogram that only assesses systolic function could lead to the erroneous conclusion that their symptoms were not cardiac in origin, thereby preventing the patient from getting proper treatment. Thus, it is important to also assess for the presence of DD in dyspneic ED patients.

Agreement between EPs and cardiology on the grade of DD was moderate. When all DEs were included, weighted $\kappa = 0.52$ (95% CI, 0.38-0.67); when excluding scans with indeterminate diastolic function, weighted $\kappa = 0.54$ (95% CI, 0.36-0.72). This level of agreement was lower than expected and may have been due to several factors. The largest contribution was likely the fact that, despite additional training, EP-sonographers lacked the technical skills needed to grade diastolic function. During enrollment, there was no real-time review of the DEs by the study cardiologist to ensure protocol adherence or correctness of measurements. Once images were obtained, any subsequent interpretations were limited by the quality of these images. Thus, the study cardiologist's assessments may have been affected by the quality of the EP-obtained images and the accuracy of their measurements. As discussed previously, we believe that this deficiency could be corrected with continued practice of DEs by EPs.

Multiple prior studies have shown that interobserver variability exists between cardiologists interpreting left ventricular systolic function as well as diastolic function [17,25,26]. Thus, we had additional cardiologists independently review and interpret the images. To attempt to control for potential institutional/regional differences in practice, we included 2 additional cardiologists: one from the same institution as the primary cardiologist and one from a different institution. Agreement among the 3 cardiologists ranged from poor to moderate (Table 4). Although these results could be due to the overall quality of the EP-obtained images, they highlight several salient points about performance and interpretation of a DE. First, even within the confines of a simplified protocol such as ours, there is some degree of subjectivity when assessing diastolic function. Alternatively, it may be that even though we attempted to use simplified, predefined methods for grading DD, because of the expertise of the cardiologists, information that was not part of our predefined criteria was unintentionally used in assigning grade of DD. To explore this possibility, several cases with discrepant interpretations were reviewed with the study cardiologist after completion of data analysis. This review revealed 2 cases that EPs rated as abnormal based on Doppler parameters that the cardiologist felt were due to volume depletion and thus diastolic function was rated as normal. In addition, subtle wall-motion abnormalities altered assessment of diastolic function in at least 3 cases. This highlights not only the difficulty of the DE itself but also the challenge of designing a diastology protocol for use by EPs that optimizes accuracy without becoming so difficult or time consuming that its feasibility suffers.

Agreement between EPs and comprehensive echocardiography results was poor to moderate; the same was true for agreement between the study cardiologist and the comprehensive echocardiography results (Table 3). These results, although of limited utility because of the small number of patients who had a comprehensive echocardiogram, are not unexpected. Multiple reasons may account for this relatively poor agreement. As discussed previously, there is baseline variability between raters interpreting the same images. In addition, comprehensive echocardiograms were generally performed several hours to several days after admission. Because of the dynamic nature of acutely decompensated heart failure, it is possible that diastolic parameters on comprehensive echocardiography changed in response to treatment [15,21,26,27] and did not accurately represent the patients' clinical

Table 4
Interrater reliability for interpretations by cardiologists

	κ (95% CI)	Weighted κ (95% CI)
C1/C2 (all)	0.12 (0.00-0.28)	0.28 (0.14-0.42)
C1/C2 (Indt excl.)	0.17 (0.00-0.41)	0.31 (0.11-0.51)
C1/C3 (all)	0.15 (0.00-0.33)	0.28 (0.14-0.43)
C1/C3 (Indt excl.)	0.22 (0.00-0.47)	0.32 (0.09-0.55)
C2/C3 (all)	0.59 (0.39-0.79)	0.67 (0.48-0.87)
C2/C3 (Indt excl.)	0.58 (0.32-0.84)	0.60 (0.32-0.88)

Abbreviations: C1 = study cardiologist; C2 = cardiologist #2; C3 = cardiologist #3.

condition on presentation to the ED. In addition, comprehensive echocardiograms include additional views and measurements not included in our simplified protocol. This may have also contributed to the discrepancy.

Agreement between EP-sonographers was good with 95% agreement on normal vs abnormal diastolic function, with $\kappa = 0.66$ (95% CI, 0.39-0.92) and weighted $\kappa = 0.77$ (95% CI, 0.56-0.96) for grade of DD. There was also 95% agreement on presence of clinically significant DD. This demonstrates the high reliability of the EP-performed DE, which is important because it shows that EPs were able to consistently follow a multistep protocol and reach similar conclusions. This suggests that small refinements of our DE protocol that increase accuracy can reasonably be expected to be performed correctly by EPs, thereby increasing the overall utility of the examination.

Ünlüer et al [14] previously examined EPs' ability to identify DD using bedside echocardiography. Their reported sensitivity and specificity for an EP-performed DE were 89% (95% CI, 77-95) and 80% (95% CI, 51-95), respectively. Compared to these results, our study showed better sensitivity (100 vs 89%) but lower specificity (47 vs 80%).

Their study differed from ours in several important ways that could account for these differences. The most salient difference was that Ünlüer et al only attempted to identify normal vs abnormal diastolic function and did not endeavor to grade the level of dysfunction. To our knowledge, ours is the first study to assess EPs' ability to accurately grade the level of a patient's DD. Although, as previously mentioned, our results indicate that EPs need additional training beyond what was provided as part of our protocol, we feel that identification of clinically significant DD is a crucial part of an EP-performed DE. For example, a patient who presents with severe dyspnea, hypoxia, mildly reduced ejection fraction, and grade 3 DD may benefit from treatment for acute DHF [28,29], whereas a patient who presents with the same symptoms but has only grade 1 DD may benefit from further investigation for an alternative etiology of their symptoms.

Another key difference between the Ünlüer et al study and ours was the methodology used for evaluating diastolic function. They did not include use of TDI, which is recommended by the American Society of Echocardiography [15]. There are myriad reasons that TDI has become a standard part of a DE, including variability of Doppler mitral inflow parameters across the spectrum of DD such that patients with normal hearts may have similar values to those with significant cardiac disease [15,30]. Although more technically difficult, we choose to include TDI as part of our protocol because we felt that it would lead to more accurate results. However, our data indicate that, at this time, EPs would benefit from increased training in the use of TDI as part of a DE.

We believe that performance and interpretation of a DE are important and potentially useful skills for EPs to acquire. Given the prevalence of DD, it is likely that patients with this disease will present to the ED and could benefit from early recognition of this as the primary etiology of their dyspnea. For example, a DE might raise treating clinicians' confidence in their diagnosis, thereby improving resource utilization by decreasing use of unnecessary additional studies (such as computed tomographic scans). In addition, DD, alone or in combination with systolic dysfunction, suggests a worse prognosis and may require alternative treatment approaches [8,11,26,27] or changes in patient disposition. Our results show that EPs are able to exclude clinically significant DD but are not yet able to reliably grade DD. Determination of the extent, methods, and cost (both in time and in money) of training necessary for EPs to become proficient in DEs, as well as their impact on direct, patient-oriented outcomes, represents an area for continued research.

5. Limitations

Our study has several important limitations. First, it was designed as an expert-level study; and all bedside echocardiograms were performed by EPs with fellowship training in ultrasound. This limits the generalizability of our results, as the technical skills necessary to perform and interpret a DE are outside of the normal scope of practice for most EPs.

Future areas of research should assess the accuracy and feasibility of our protocol as performed by less experienced sonographers.

Another limitation of our study is that we enrolled a convenience sample of patients at a single institution, which likely introduced selection bias. Furthermore, despite being powered to detect a clinically significant agreement between cardiology and EPs for presence and grade of DD, the overall sample size was small.

Another consequence of the small sample size was the small number of DEs available (25-29) for comparison when interobserver variability between cardiologists was assessed. The small number of examinations compared led to wide CIs, thereby making it difficult to draw firm conclusions about the overall validity of these results.

Finally, although the study cardiologist did not rate any of our DEs as being technically inadequate to provide an interpretation of diastolic function, he was limited to interpretation of EP-obtained images and measurements, which may or may not have been accurate. Contemporaneous performance of a comprehensive echocardiogram would have improved the external validity of our measurements and subsequent conclusions about diastolic function.

6. Conclusions

In summary, our results indicate that a DE performed by an expert EP-sonographer is highly sensitive for detecting clinically significant DD. Correct grading of DD, although likely to provide a clinical benefit to a subset of ED patients, is a more technically difficult skill that requires further practice and study before it can be routinely used by EPs.

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