Feasibility of point-of-care echocardiography by internal medicine house staff

John H. Alexander, MD, MS,[a] Eric D. Peterson, MD, MPH,[a] Anita Y. Chen, MS,[b] Tina M. Harding, BSN,[b] David B. Adams, RDCS,[a] and Joseph A. Kisslo, Jr, MD[a] *Durham, NC*

Objective To determine whether internal medicine house staff with limited training in echocardiography can use point-of-care echocardiography to make simple, clinically important diagnoses.

Background Availability of small, portable ultrasound devices could make point-of-care echocardiography widely available. The training required to perform point-of-care echocardiography has not been established.

Methods Medical house staff participated in a 3-hour point-of-care echocardiography training program. Patients scheduled for standard echocardiography as part of clinical care underwent point-of-care echocardiography within 24 hours to assess four common clinically important diagnoses. Each standard echocardiogram was interpreted twice. Agreement (κ) was calculated between point-of-care and standard echocardiography by using standard echocardiography as the gold standard and between the two interpretations of standard echocardiography.

Results Agreement (κ) between point-of-care echocardiography and standard echocardiography was 75% (0.51) for left ventricular dysfunction (ejection fraction <55%), 79% (0.31) for moderate or severe mitral regurgitation, 92% (0.32) for aortic valve thickening or immobility, and 98% (0.51) for moderate or large pericardial effusion. Agreement between the two interpretations of standard echocardiography was 83% (0.63) for left ventricular dysfunction, 92% (0.68) for moderate or severe mitral regurgitation, 95% (0.62) for aortic valve thickening or immobility, and 97% (0.53) for moderate or large pericardial effusion.

Conclusions Medical house staff with limited training in echocardiography can use point-of-care echocardiography to assess left ventricular function and pericardial effusion with moderate accuracy that is lower than that of standard echocardiography. Assessment of valvular disease and other diagnoses likely requires more training and/or experience in echocardiography. (Am Heart J 2004;147:476–81.)

Traditionally, physicians have relied on the physical examination to screen for important structural cardiac abnormalities, including left ventricular (LV) dysfunction and valve disease. The ability of practicing physicians to detect cardiac pathology with the use of these techniques, however, has been questioned.[1-3] Diagnostic echocardiography offers a practical alternative for the evaluation of important cardiac pathology; however, significant equipment costs and the time and training necessary to complete a full echocardiographic examination limit access and create delays in getting important results to the bedside.[4,5] Despite current recommendations, a substantial proportion of patients with suspected and even overt cardiac pathology do not undergo evaluation of LV function and valve disease.[6,7]

Recently, several small, light, and inexpensive point-of-care (POC) echocardiography devices have become available. These devices could potentially make echocardiography available to many more physicians at the bedside and are being used increasingly by without formal training in echocardiography. Despite the technology's promise, it remains uncertain whether physicians with limited formal training in echocardiography can use these devices to answer even simple clinical questions. Appreciating the limitations of POC ultrasound in the hands of inexperienced users is critical to the incorporation of this promising technology into medical practice.

From [a]Duke University Medical Center and the [b]Duke Clinical Research Institute, Durham, NC.

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Reprint requests: John H Alexander, MD, MS, Duke Clinical Research Institute, P.O. Box 3850, Durham, NC, 27715.

E-mail: alexa017@mc.duke.edu

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The purposes of this study were (1) to design a simple POC echocardiography training program for physicians without prior experience in echocardiography and (2) to compare the accuracy of POC and standard transthoracic echocardiography in the assessment of four common and clinically important diagnoses.

Methods

Patients

Patients scheduled to have a standard transthoracic echocardiogram performed within 24 hours as part of their clinical care were eligible for inclusion.

Investigator training

Duke University Medical Center medical house staff without prior echocardiography training participated in a standardized 3-hour training program. The program included a review of basic ultrasound principles; operation of the "OptiGo" ultrasound device (Agilent Technologies, Inc, now Phillips Medical Systems, Andover, Mass); use of depth, gain, and color Doppler controls; interpretation of 2-D echocardiographic images to assess LV systolic dysfunction, pericardial effusion, and aortic valve disease (thickening and mobility); interpretation of color Doppler evaluation of mitral regurgitation; and hands-on 2-D and color Doppler imaging by using the parasternal long-axis, midventricular parasternal short-axis, and apical 4-chamber views. Approximately half of this 3-hour training period was spent performing hands-on imaging under the guidance of an experienced cardiac sonographer.

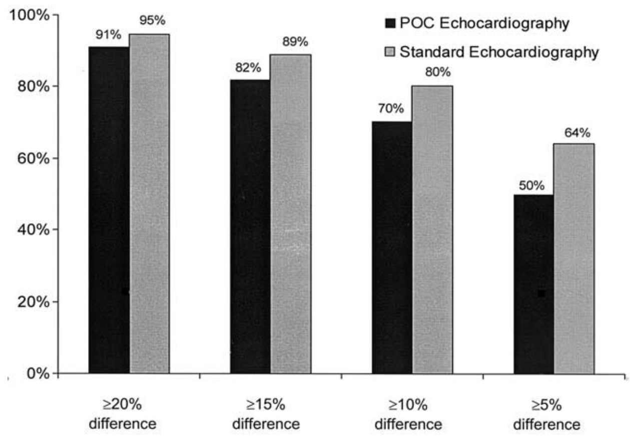
Protocol

The Duke University Medical Center Institutional Review Board approved the protocol. All patients gave written informed consent before participation.

Using the OptiGo ultrasound device, each investigator performed a brief POC echocardiogram to assess each of the 4 targeted diagnoses. They recorded their assessment of the patient's LV ejection fraction to the nearest 5% and whether the patient had moderate or greater mitral regurgitation, significant aortic valve disease (defined as moderate or greater thickening or immobility), or moderate or greater pericardial effusion. If they were unable to obtain images adequate to make a diagnosis, they recorded that the study was indeterminate for that diagnoses.

Each patient's standard echocardiogram was interpreted in the usual clinical fashion by an experienced Duke Medical Center echocardiographer who was blinded to the results of the POC echocardiogram. Ejection fraction was assessed to the nearest 5%. Each standard echocardiogram report was then reviewed for LV ejection fraction and the presence of moderate or greater mitral regurgitation, significant aortic valve disease (defined as moderate or greater thickening or immobility), moderate or greater pericardial effusion, and other clinically important diagnoses. Each standard echocardiogram was also interpreted a second time, with the use of similar methodology and blinded to the first interpretation, by a single experienced observer to investigate the variability in standard echocardiography.

Figure 1



Agreement rate between POC and standard echocardiography and between 2 interpretations of standard echocardiography for LV ejection fraction using a range of absolute differences in LV ejection fraction as criteria for agreement.

The study staff collected additional medical history and demographic information from the patient's medical record. The indication for the standard echocardiogram was determined from the written order. All data were entered into a standard SAS database for analysis.

Statistical analysis

Dichotomous variables are expressed as percentages and continuous variables as either means or medians. Indeterminate responses are excluded in subsequent analyses.

Rates of agreement were calculated between the POC and standard echocardiograms and between the two interpretations of the standard echocardiogram for each diagnosis. Disagreement in LV ejection fraction was defined both dichotomously, with <55% being abnormal and ≥55% being normal, and using a variety of absolute differences in LV ejection fraction ranging from 5% to 20%. Because of high rates of agreement due to chance, κ statistics were determined for each comparison. The sensitivity, specificity, and positive and negative predictive values of POC echocardiography were calculated with the use of standard echocardiography as the gold standard. Finally, to assess whether a "learning curve" could be detected, we assessed agreement between POC and standard echocardiography in the assessment of LV dysfunction (defined dichotomously as <55% or ≥55%) across quartiles of investigator experience.

Results

Investigators and patients

Twenty Duke University Medical Center house staff participated in 1 of 5 POC echocardiography training programs. They enrolled 537 patients between April 18, 2000, and November 1, 2000. Three patients were

Table I. Baseline demographics and standard echocardiography findings

Characteristic	No. = 533
Median age (y)	59.2
Male sex (%)	52.9
Obese (body mass index ≥30) (%)	32.8
Chronic obstructive pulmonary disease (%)	14.8
Patient positionable on side (%)	79.0
Indication for standard echocardiography (%)	
LV ejection fraction	77.3
Murmur	15.2
Pericardial effusion	6.9
Standard echocardiography findings (%)	
LV ejection fraction	
≤15%–25%	14.5
30%–40%	13.3
45%–50%	13.7
≥55%	58.2
Mitral regurgitation	15.8
Aortic valve disease	6.8
Pericardial effusion	2.4
POC echocardiography location (%)	
Intermediate-care unit	67.7
Echocardiographic laboratory	22.3
Intensive care unit	9.9
Time to complete POC echocardiogram, mean (min, max), minutes	8.48 (3, 20)

Table II. Agreement and κ statistics between POC echocardiography and standard echocardiography and between 2 interpretations of standard echocardiography

	Agreement	κ
LV function		
POC echocardiography	75%	0.51
Standard echocardiography	83%	0.63
Mitral regurgitation		
POC echocardiography	79%	0.31
Standard echocardiography	92%	0.68
Aortic valve disease		
POC echocardiography	92%	0.32
Standard echocardiography	95%	0.62
Pericardial effusion		
POC echocardiography	98%	0.51
Standard echocardiography	97%	0.53

"Indeterminate" responses are excluded.

excluded because their POC and standard echocardiograms were performed >72 hours apart, and 1 patient was excluded because he was <18 years old.

Baseline characteristics

Baseline demographics and standard echocardiogram findings for the remaining 533 patients are shown in Table I. The majority of echocardiograms (77%) were ordered to assess LV systolic function. Most POC echocardiograms were performed in intermediate-care units (68%). The average time required to complete a POC echocardiogram was 8.5 minutes.

POC echocardiography

Compared with standard echocardiography, POC echocardiography resulted in more indeterminate responses for LV function (7 vs 2), mitral regurgitation (39 vs 28), aortic valve thickening or immobility (55 vs 5), and pericardial effusion (11 vs 0).

Agreement (κ) between POC echocardiography and standard echocardiography was 75% (0.51) for LV dysfunction, 79% (0.31) for moderate or severe mitral regurgitation, 92% (0.32) for aortic valve thickening or immobility, and 98% (0.51) for moderate or large pericardial effusion (Table II). The sensitivity, specificity, positive predictive value, and negative predictive value of POC echocardiography compared with standard echocardiography for each diagnosis is shown in Table III. There was no evidence of a significant "learning curve," with agreement rates between POC and standard echocardiography for LV dysfunction of 79%, 72%, 71%, and 75% in the 1st, 2nd, 3rd, and 4th quartiles, respectively.

Standard echocardiography interobserver agreement

Agreement (κ) between two interpretations of standard echocardiography was 83% (0.63) for LV dysfunction, 92% (0.68) for moderate or severe mitral regurgitation, 95% (0.62) for aortic valve thickening or immobility, and 97% (0.53) for moderate or large pericardial effusion.

Agreement rates between POC echocardiography and standard echocardiography and between the two interpretations of standard echocardiography for assessment of LV ejection fraction, using various absolute criteria for agreement, are shown in Figure 1. With the use of a 20% absolute difference in LV ejection fraction as criteria for agreement, the agreement between POC and standard echocardiography was 91%. This is slightly lower than the 95% interobserver agreement in standard echocardiography with the use of the same criteria. As the criteria for agreement are tightened, rates of agreement decline; however, the relative difference between POC and standard echocardiography remains similar.

Discussion

Small, portable, cardiac ultrasound machines have the potential to revolutionize patient care by making cardiac ultrasound available to all clinicians. Application of this new technology, however, requires skills on the part of human users. We found that with as little as 3 hours of training, medical residents could use POC echocardiography to answer simple but com-

Table III. Sensitivity, specificity, positive predictive value, and negative predictive value of POC echocardiography compared to standard echocardiography

	Sensitivity	Specificity	Positive predictive value	Negative predictive value
LV dysfunction (%)	82	71	67	85
Mitral regurgitation (%)	48	85	40	89
Aortic valve disease (%)	29	97	46	95
Pericardial effusion (%)	54	99	50	99

mon and important clinical questions. Assessment of LV dysfunction and pericardial effusion was possible with a moderate level of agreement with standard echocardiography. Ability to assess mitral regurgitation and aortic valve disease, however, was less good and probably reflects that additional training and/or experience is required for the accurate assessment of more complex diagnoses that require color flow Doppler or precise 2-D imaging. This study adds to the limited but critical literature on the use of POC ultrasound in the hands of less experienced users.

Limitations of physical examination

In most medical practices, screening for cardiac pathology currently relies on a careful history and physical examination. Unfortunately, physical examination is relatively inaccurate for assessing important cardiovascular pathology. Medical house staff frequently fail to identify important cardiovascular findings by auscultation.[1,2] One study found sensitivity of 0% to 37% and specificity of 85% to 100% with auscultation for regurgitant valve lesions, which depended heavily on the experience of the examiner.[8] Clinical evaluation of LV dysfunction, even including the electrocardiogram and chest radiography, has a sensitivity and specificity of only 81% and 47%, respectively.[9] The availability of POC echocardiography could improve diagnostic accuracy and also substantially increase, in a cost-effective way, the recommended screening for LV systolic dysfunction, much of which currently goes undiagnosed.[6,7,10]

POC echocardiography

The idea of POC echocardiography was introduced in 1978.[11] The usefulness of POC echocardiography has been studied in assessment of LV function, regional wall motion, hypertrophy, chamber size, regurgitant valve lesions, and pericardial effusion.[12–25] Most studies, however, have investigated POC echocardiography performed either by a trained sonographer or an experienced cardiologist. To understand whether and how POC echocardiography can be used in clinical care, however, it is critical to understand whether it can be performed by those with less experience than currently required for standard echocardiography.

A number of prior studies have investigated POC echocardiography by physicians without formal echocardiography training using either (1) a 2-month training program,[26] (2) “inexperienced” cardiologists or cardiology fellows,[27] or (3) 20-hour didactic program followed by performance of 20 supervised transthoracic studies.[28] Bruce et al,[27] who compared physical examination and POC echocardiography performed by cardiologists with standard echocardiography, found that POC echocardiography reduced the number of “missed findings” from 59% to 29%. In the study most similar to ours, DeCara et al developed a significantly more intensive POC echocardiographic training program for medical residents and then compared them with experienced echocardiographers using POC echocardiography. They found that compared with experienced echocardiographers, medical residents using POC echocardiography had a slightly lower sensitivity (88% vs 80%) and specificity (98% vs 97%) for clinically important findings and similar sensitivity (65% vs 63%) and specificity (95% vs 92%) for all findings.[28] Importantly, by comparing both inexperienced and experienced users of POC echocardiography with standard echocardiography, they accounted for the inherent variability in echocardiography. A final, older study of 12 highly selected patients found that physicians with just 2 hours of training could use POC echocardiography to improve on their ability on physical examination to differentiate patients with normal and moderately abnormal LV function.[29] Our data support the idea that physicians with limited training can use a focused POC echocardiography examination to assess LV function and pericardial effusion albeit with lower precision than current standard echocardiography.

The POC echocardiogram should not be considered a replacement for standard echocardiography. In practice, patients with other suspected abnormalities, poor sound transmission, or indeterminate or abnormal findings on POC echocardiography should be referred for standard echocardiography or other appropriate diagnostic testing. Importantly, we found a significantly higher rate of indeterminate findings with inexperienced users of POC echocardiography. As experience with POC echocardiography grows, individual physicians, professional societies, and health care organizations will determine whether and how POC echocardiography should be integrated into medical practice. Fortunately, these issues are beginning to be explored in the medical literature.[30–32]

Although it is rarely addressed directly, the introduction of a new diagnostic technology raises questions about the training and experience necessary for its use. We found that with just a few hours of training, medical house staff could use POC echocardiography to assess LV function and pericardial effusion, albeit with somewhat less accuracy than standard echocardiography. We chose to study a 3-hour training program, recognizing that some training is desirable but that more than 3 hours would be impractical to generalize to the large number of physicians who could potentially benefit from access to POC echocardiography. This level of training is not dissimilar to the initial training that many medical students get in cardiac auscultation but is much lower than that currently recommended for use of POC echocardiography.[33] Although it is tempting to assume that additional experience will improve diagnostic accuracy, we did not detect a meaningful "learning curve" in our study. Whether similar results can be obtained with other groups of physicians and how additional training and experience will affect diagnostic accuracy will require additional research.

Standard echocardiography interobserver agreement

We chose to compare POC echocardiography with standard echocardiography. The assessment of any new diagnostic test requires comparison to some gold standard. Although standard echocardiography is an accepted standard for the assessment of LV dysfunction, mitral regurgitation, aortic valve disease, and pericardial effusion, there remains substantial interobserver variability in the interpretation of echocardiographic images. Our study is unique in this area in that it includes a systematic and direct assessment of the interobserver variability among experienced echocardiographers. Kappa statistics of 0.53 to 0.68 suggest that there is only moderate (κ 0.4 to 0.6) to substantial (κ 0.6 to 0.8) interobserver agreement between two experienced echocardiographers interpreting the same echocardiographic images. Comparing POC directly with standard echocardiography, as if 100% agreement is possible, is misleading and fails to recognize the variability inherent in echocardiography as it is used today. Other investigators have used other techniques to control for this variability such as comparing both inexperienced and experienced users of POC echocardiography with standard echocardiography.[28] Some of the variability in standard echocardiography is attributable to the semiquantitative methods that we used to estimate LV function, the severity of valve regurgitation, and the size of pericardial effusions. More quantitative methods to assess these abnormalities exist, and their use might have lead to different results. These methods, however, are rarely used clinically.

Limitations

These results may not be generalizable to other populations with a lower or higher prevalence of disease. We used medical house staff as investigators; the performance of POC echocardiography by other physicians or nonphysicians may be different. Furthermore, we studied POC echocardiography after a 3-hour training program; more or less training probably will affect its diagnostic accuracy. Because we categorized diagnoses as yes or no, some disagreements may be disagreements about severity rather than the presence of abnormalities. Finally, we only focused on 4 clinically important diagnoses. Depending on the capabilities of the POC echocardiography device and the training and experience of the user, POC echocardiography may be inadequate to assess many of the other diagnoses commonly made by standard echocardiography.

Conclusions

The technology necessary for POC echocardiography is now available and is being rapidly and widely disseminated. This study suggests that with even minimal training, physicians may be able to use POC echocardiography to assess LV function and pericardial effusion, albeit with lower accuracy than that of standard echocardiography. Further research is required to determine whether and how POC echocardiography should be moved into clinical practice.

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