Accuracy of Emergency Physician Assessment of Left Ventricular Ejection Fraction and Central Venous Pressure Using Echocardiography

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Abstract

Objectives: Emergency department (ED) bedside echocardiography may offer useful information on cardiac function and volume status. The authors evaluated the accuracy of emergency physician (EP) performance of echocardiography in the assessment of left ventricular ejection fraction (LVEF) and central venous pressure (CVP). **Methods:** The authors conducted a cross-sectional observational study at an urban teaching ED, involving a convenience sample of patients presenting to the ED between September 2000 and February 2001. Level III–credentialed EP sonographers who had undergone a three-hour training session in limited echocardiography, focusing on LVEF and CVP measurement, performed echocardiograms. Vital signs and indication for echocardiography were documented on a study data sheet. LVEF was rated as poor (<30%), moderate (30%–55%), or normal (>55%) and an absolute percentage. Central venous pressure categories included low (<5 cm), moderate (5–10 cm), and high (>10 cm). Formal echocardiograms were obtained within a four-hour window on all patients and interpreted by a staff cardiologist. Correlation analysis was performed using the κ correlation coefficient for LVEF and CVP categories and a Pearson correlation coefficient for LVEF measurement. **Results:** A total of 115 patients were assessed for LVEF, and 94 patients had complete information for CVP. Indications for echocardiography included chest pain (45.1%), congestive heart failure (38.1%), dyspnea (5.7%), and endocarditis (10.6%). Results showed a LVEF correlation of $r^2 = 0.712$ with 86.1% overall agreement. Subgroup analysis revealed the highest agreement (92.3%) between EP and formal echocardiograms within the normal LVEF category, followed by 70.4% agreement in the poor LVEF category and 47.8% in the moderate LVEF category. Central venous pressure measurements resulted in 70.2% overall raw agreement between EP and formal echocardiograms. Subgroup analysis revealed the highest agreement (83.3%) within the high CVP category followed by 66.6% in the moderate and 20% in the low categories. **Conclusions:** Experienced EP sonographers with a small amount of focused additional training in limited bedside echocardiography can assess LVEF accurately in the ED. **Key words:** echocardiography; emergency medicine; left ventricular ejection fraction; inferior vena cava; ultrasound. ACADEMIC EMERGENCY MEDICINE 2003; 10:973–977.

Emergency physicians (EPs) routinely are called on to manage critically ill patients who may present with an indeterminate or changing hemodynamic status. Early in the patient's course, it may be difficult to firmly identify the underlying etiology. At this stage, successful management hinges less on an accurate diagnosis than on a timely determination of the prevailing hemodynamic process.[1] To this end, the physical examination has been shown to be remarkably unreliable,[2,3] whereas more invasive assessments of hemodynamics are effort-intensive,[4,5] costly, and associated with significant morbidity[6–11] and mortality.[12] Bedside echocardiography offers a noninvasive, prompt method of evaluating cardiac function. Real-time assessment of the left ventricular ejection fraction (LVEF) offers a window into the causative or compensatory role that the left ventricle (LV) may play in the patient's disease process.[13] Similarly, echocardiography estimates of central venous pressure (CVP) can provide insight into cardiac preload or overall volume status or both.[14] This information can direct initial resuscitation efforts, gauge the response to therapy, focus early diagnostic testing, and provide important prognostic data.[15]

To date, evaluation of goal-directed emergency department (ED) echocardiography has focused on the diagnosis of pericardial effusions, particularly in the setting of trauma. For this indication, EPs have shown excellent proficiency, with one study finding 97.5% concordance with examinations performed by the reference echocardiology laboratory.[16] A study by Moore et al.[17] found 84% agreement between ED sonographers and cardiologists in determination of LVEF in hypotensive patients. The role of ultrasound in emergency medicine as a diagnostic tool and as

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a guide to therapy is expanding rapidly.[18–20] This article reviews the ability of EPs to extract basic hemodynamic information in the form of LVEF and CVP from EP-performed echocardiography. This expanded role for ED ultrasound could have important implications for the practice and specialty of emergency medicine.

METHODS

Study Design. This was a cross-sectional observational study. This study was approved by the institutional review board, and patients provided informed consent for enrollment.

Study Setting and Population. The study was conducted at an urban, adult, academic ED serving a population of approximately 65,000 patients per year. The investigators involved in the study were four ED attending physicians, three residents, and one physician assistant. Each investigator possessed hospital privileges to perform limited ED ultrasound and had achieved level III status for ultrasound proficiency. This latter designation identifies providers who had completed an emergency medicine ultrasound workshop, consisting of didactic and practical sessions, with a minimum of 150 proctored examinations (trauma, abdominal, aorta, and gynecologic).

Patients were enrolled as a convenience sample during a six-month period from September 2000 to February 2001. Patients were eligible for inclusion if they underwent formal echocardiography in the ED as part of their routine evaluation, regardless of the indication. Patients were enrolled when an investigator was available to perform ED echocardiography and if the formal echocardiogram would be performed within four hours of the ED echocardiogram. Patients were excluded if there was more than a four-hour delay between echocardiograms, if patients refused to consent to an ED echocardiogram, or if the investigator was aware of the results of the formal echocardiogram or any prior echocardiogram results.

Study Protocol. Before the study, each investigator received additional ultrasound training in the area of limited echocardiography. This expanded training consisted of a three-hour didactic session; a series review of normal and abnormal echocardiograms; and a minimum of five proctored examinations on unenrolled ED patients, performed in the presence of the lead investigator. Specific emphasis was placed on the technique for subjective estimation of LVEF and inferior vena cava (IVC) volume.

Emergency department sonographers were asked to complete a patient data entry and data form. Patient demographics, including age, gender, vital signs, pulse oximetry, comorbidity, and indication for formal echocardiography, were recorded. Treating physicians were not informed of the results of the ED echocardiogram to prevent any potential morbidity from the use of a misinterpreted examination.

All patients underwent ED and formal echocardiograms during their ED assessment. ED scans were performed using a Hewlett-Packard Sonos 1000 with a 2.5-MHz transducer. Each examination included an estimate of LVEF and CVP as a function of IVC volume. The technique for determining LVEF was restricted to a subjective, visual estimation of the change in LV size between diastole and systole, measured in a minimum of two planes. Visual estimation has been shown to be as accurate or in some cases superior to computerized echocardiographic estimation of LVEF, using cross-sectional diameter measurements.[21,22] The most common scanning planes used were the subcostal, parasternal short-axis, and four-chamber views.[23,24] Left ventricular ejection fraction was expressed as an absolute percentage and categorized as poor (<30%), moderate (30%–55%), or normal (>55%) in accordance with our institution's echocardiography guidelines.[25,26] Central venous pressure was estimated on the basis of IVC volume as expressed by IVC diameter and observing cyclical variation in size during respiration with and without the "sniff test."[27] Central venous pressure was categorized as low (<5 cm), medium (5–10 cm), or high (>10 cm). A complete collapse of the IVC with inspiration was accepted as evidence for a low CVP. A respiratory increase of IVC diameter equal to or greater than 50% was used to categorize a medium CVP. A respiratory decrease of IVC diameter of less than 50% was used to categorize an elevated CVP.[28] We did not obtain quantitative measurements of CVP in any of the study patients, and our technique for estimating CVP was analogous to that used by our institution's sonographers. The most common imaging plane for assessment of the IVC was the longitudinal view at the junction of the IVC and the right atrium.

All patients underwent formal echocardiography in the ED. These studies were performed using a Sonos 5500 by one of the institution's licensed sonographers and later overread by a single boarded cardiologist with extensive training and experience in echocardiogram interpretation. This official echocardiogram was regarded as the criterion standard against which the ED studies were compared.

Data Analysis. Categorical data are reported as absolute numbers with frequency percent and, when appropriate, range. Continuous data are reported with mean, SD, and range. Contingency tables are used to present raw agreement between cardiologist and ED investigators with regard to ejection fraction (EF) and IVC categories. Sensitivity and specificity are calculated for the ED investigators using the cardiologist as the criterion standard. These are reported with 95% confidence intervals (CIs). Concordance or

agreement and correlation analysis was performed by using the Cohen's weighted κ statistic for categories, and the Pearson correlation coefficient for EF measurements.

RESULTS

A total of 115 patients were enrolled in the study between September 2000 and February 2001. The mean age (± SD) for the sample population was 54.2 (± 14.9) years (range 21–91 years). The gender distribution was 62.6% ($n = 77$) male. Baseline systolic blood pressure was 132.1 (± 30) mm Hg (range 80–238 mm Hg), and baseline diastolic blood pressure was 75.1 (± 15.7) mm Hg (range 40–120 mm Hg). Mean heart rate was 86.4 (± 17.8) beats/min (range 50–132 beats/min). The mean respiratory rate was 20.3 (± 3.7) breaths/min (range 14–40 breaths/min). The mean oxygen saturation by pulse oximetry was reported at 95.3% (± 4.8%) (range 64%–100%) on room air. Pre-existing medical conditions in the study patients are described in Table 1.

The most common indication for obtaining a formal two-dimensional echocardiographic study was to evaluate the presenting complaint of chest pain (45.1%). Other common indications were for symptoms suggestive of congestive heart failure (34.4%), for suspected endocarditis (10.6%), or for evaluation of shortness of breath (5.7%).

All enrolled patients had complete ED data regarding EF categorization as previously described. The ED categorized 27 (23.5%) patients as having poor EF, 23 (20.0%) as having moderate EF, and 65 (56.0%) as having normal EF. The sonographer categorized 21 patients (18.3%) with poor EF, 23 (20.0%) with moderate EF, and 71 (61.7%) with normal EF. Table 2 shows the agreement between the ED and the sonographer. Overall, there was raw agreement in 90 (78.3%) patients, with a κ of 0.71 (95% CI = 53% to 89%). A calculated EF was available for 102 patients. Thirteen cases had no formal EF reported on the final echocardiography report by cardiology. The mean EF obtained using two-dimensional echocardiography by the ED investigator was 51.3% (± 20.3%) (range 10%–85%). The mean official EF obtained from the study institution sonographer was 52.5% (± 20.0%) (range 10%–80%). The degree of correlation was $r^2 = 0.72$.

Ninety-four patients had complete data regarding CVP categorization. Formal echocardiography reports neglected to report CVP data in 21 cases. The ED categorized 10 (10.6%) patients as having low CVPs, 48 (51.0%) patients as having medium CVPs, and 36 (38.3%) patients as having high CVPs. The sonographer categorized 8 (8.5%) patients as having low CVPs, 44 (46.8%) patients as having medium CVPs, and 42 (44.7%) patients as having high CVPs. Table 3 shows the agreement between the ED and the sonographer. Overall, there was raw agreement in 64 (68.1%) patients, with a κ of 0.41 (95% CI = 20% to 60%). As previously described, the sensitivity for medium (normal) CVP was calculated to be 50% (95% CI = 31% to 69%).

The missing data for LVEF ($n = 13$) and CVP ($n = 21$) was not reported by cardiology. When cardiology reviewed the tapes containing the missing data, the LVEF was unobtainable because of either technical or storage-related problems. With regards to CVP, most of the studies did not include sufficient views of the IVC to allow a final evaluation.

TABLE 1. Significant Medical History

Hypertension	43.47%
Congestive heart failure	38.13%
Coronary artery disease	22.6%
Myocardial infarction	7.82%
Endocarditis	12.17%
Cardiomyopathy	6.08%

TABLE 2. Ejection Fraction Categorization*

	ED Investigator		
Cardiologist	Poor No. (%)	Moderate No. (%)	Normal No. (%)
Poor no. (%)	19 (**70.37**)	2 (8.7)	0 (0)
Moderate no. (%)	7 (25.93)	11 (**47.83**)	5 (7.69)
Normal no. (%)	1 (3.7)	10 (43.48)	60 (**92.31**)

*Numbers in bold represent % raw agreement between emergency department (ED) investigator and cardiologist.

DISCUSSION

This study suggests that ED sonographers, with minimal additional training, can perform limited echocardiography successfully for the purposes of obtaining basic hemodynamic information. For this criterion, the highest agreement was found in the subgroup of patients with normal EFs, followed by patients with low EFs. From a clinical perspective, these subgroups represent patients whose hemodynamic information would seem to offer the greatest value. If clinical shock or undifferentiated hypotension is present, the physician may entertain a number of possible diagnoses, each potentially leading down a different or competing therapeutic path. A normal LVEF in a patient with unexplained hypotension or

TABLE 3. Central Venous Pressure Categorization*

	ED Investigator		
Cardiologist	Low No. (%)	Medium No. (%)	High No. (%)
Low no. (%)	2 (**20.0**)	4 (8.33)	2 (5.56)
Medium no. (%)	8 (80.0)	32 (**66.67**)	4 (11.11)
High no. (%)	0 (0)	12 (25.0)	30 (**70.59**)

*Numbers in bold represent % raw agreement between emergency department (ED) investigator and cardiologist.

shock may direct the physician away from primary pump failure as an etiology toward a broader differential diagnosis and management strategy. Similarly, if the same patient shows a poor LVEF, LV failure is a likely culprit, and inotropic support might be required. Among the discordant studies, no patient with poor LVEF was categorized as having a normal LVEF, and vice versa, implying that large magnitude false-positive or false-negative results did not occur.

Overall agreement for CVP was less than that of LVEF. There were several possible reasons for this. It is our impression that CVP estimates by echocardiography are more subjective than LVEF estimates. The positioning of the patient, the degree of inspiration, and the relative influence of IVC size versus the respiratory variation all may introduce interoperator error into the CVP measurement. Real-time interobserver assessment in the same clinical circumstance may clarify the extent to which these components affect interpretation of CVP. For the hypotensive-normal LVEF patient described earlier, a small IVC would suggest inadequate intravascular volume. In the same patient, a large IVC implies elevated right-side pressures: right ventricular infarction, pulmonary embolism, or pulmonary hypertension.

LIMITATIONS

Potential sources of error in our study included the possibility of patient sampling (convenience sampling). Some investigators may have enrolled only patients they felt most confident about scanning, potentially biasing our results. We also did not account for changes in cardiac function or hemodynamics secondary to any interventions the study patients may have received during the interval to formal echocardiography. More critical patients may be overrepresented because clinicians may be more invested in obtaining the echocardiography information for purposes of clinical management. Overall the results were obtained in a patient population preselected to undergo formal echocardiography. As such, they represent the patient group most likely to benefit from limited ED echocardiography with a relatively higher pretest likelihood of disease relative to the general ED population. There was no outcome assessment related to the use of echocardiography in the ED. It remains unclear to what extent the application of limited echocardiography may change management or practice. This uncertainty is underscored by the high percentage of patients undergoing echocardiography for chest pain–related complaints. Although LV function can be an important determinant of prognosis in myocardial infarction, it is likely that most of these patients would fall into the normal or moderate LVEF categories. In addition, our study was not designed to evaluate LVEF and CVP in patients with undifferentiated hypotension, and as such, our results cannot be extrapolated to that patient population, and we could not presumptively expect a positive impact on the management and outcome in these patients. With regards to CVP measurement itself, we realize our determination of the CVP is an indirect measurement and not a true barometric value; however, we believe our measurements correlate well with objective pressures.

Each of our studies was overread by our institution's staff cardiologist, who served as the criterion standard. We did not control for interobserver concordance, given that our hospital protocol provides for review by one cardiologist only.

Our studies were performed on a first-generation ultrasound machine, which, compared with the fifth-generation machine (Sonos 5500) used by the cardiology department, provided us with lesser quality images. Despite this fact, it is apparent that we were able to obtain a high degree of agreement with the cardiology department.

CONCLUSIONS

Our study, along with that of Moore et al.,[17] confirms that EP sonographers are capable of obtaining images that allow accurate assessment of LVEF. Emergency physicians capable of using this imaging modality are in a unique position to obtain real-time information and incorporate it with their clinical assessments to facilitate management of their patients. Emergency department performance of echocardiography to obtain estimates of LVEF and CVP may prevent delays in obtaining this information in circumstances where there is limited availability of sonographic technical support.[29]

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