Bedside Echocardiography by Emergency Physicians

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Study objective: Timely diagnosis of a pericardial effusion is often critical in the emergency medicine setting, and echocardiography provides the only reliable method of diagnosis at the bedside. We attempt to determine the accuracy of bedside echocardiography as performed by emergency physicians to detect pericardial effusions in a variety of high-risk populations.

Methods: Emergency patients presenting with high-risk criteria for the diagnosis of pericardial effusion underwent emergency bedside 2-dimensional echocardiography by emergency physicians who were trained in ultrasonography. The presence or absence of a pericardial effusion was determined, and all images were captured on video or as thermal images. All emergency echocardiograms were subsequently reviewed by the Department of Cardiology for the presence of a pericardial effusion.

Results: During the study period, a total of 515 patients at high risk were enrolled. Of these, 103 patients were ultimately deemed to have a pericardial effusion according to the comparative standard. Emergency physicians detected pericardial effusion with a sensitivity of 96% (95% confidence interval [CI] 90.4% to 98.9%), specificity of 98% (95% CI 95.8% to 99.1%), and overall accuracy of 97.5% (95% CI 95.7% to 98.7%).

Conclusion: Echocardiography performed by emergency physicians is reliable in evaluating for pericardial effusions; this bedside diagnostic tool may be used to examine specific patients at high risk. Emergency departments incorporating bedside ultrasonography should teach focused echocardiography to evaluate the pericardium.

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INTRODUCTION

Few applications of emergency bedside ultrasonography are more time critical and potentially life-saving as 2-dimensional echocardiography.[1] It is well documented that ultrasonography can be learned by emergency physicians[2,3] and that this bedside tool is extremely valuable as part of the focused examination for trauma.[4] The ability to rapidly and accurately diagnose pericardial effusions in the emergency department facilitates a wide variety of traumatic and nontraumatic symptoms; echocardiography is the undisputed test of choice for the detection of pericardial effusion.[5] Few data exist in this focused area of emergency ultrasonography, especially in a general emergency population. This study prospectively examined the accuracy of echocardiography performed by emergency physicians in the detection of pericardial effusion.

METHODS

This study was designed to assess the accuracy of echocardiography performed by emergency physicians to detect pericardial effusions. Emergency patients at high risk were defined before the study and are outlined in Figure 1. We prospectively identified cases, and 2-dimensional echocardiography was performed on these selected patients. The captured studies were subsequently reviewed by a single echocardiographer from the Department of Cardiology to determine the presence or absence of an effusion; this overread was used as the comparative standard. This study was approved by the local institutional review board.

Los Angeles County+University of Southern California Medical Center hosts a large training program in emergency medicine, is a Level I trauma center, and has an ED that serves a local population of between 1.5 and 2 million local inhabitants. Of the 155,000 annual ED visits, approximately 3,600 to 4,000 are for major trauma patients.

Figure 1.
High-risk populations for pericardial effusions.

1. Unexplained hypotension or dyspnea
2. Cancer with chest pain or dyspnea
3. Congestive heart failure/enlarged cardiac silhouette
4. Blunt chest injury
5. Penetrating chest injury
6. Uremia with chest pain or dyspnea
7. Pericarditis
8. Systemic lupus erythematosis with chest pain or dyspnea

The study was conducted prospectively from July 1997 to December 1999. Consecutive emergency patients who were at high risk for pericardial effusion according to both criteria and physician judgement underwent 2-dimensional echocardiography performed by the treating emergency physician after informed consent. Three departmental ultrasonography machines (Aloka models 1400 and 1700, Aloka Company, Wallingford, CT; ATL 4, ATL, Bothell, WA) with 2.5- to 3.0-MHz microconvex probes were used by emergency physicians during the study period. No clinical interventions were performed on the basis of the emergency physician echocardiographic examination. If the patient was deemed to need a formal echocardiographic examination on an emergency basis, the Department of Cardiology performed the study.

All participating physicians had previously taken a standardized 16-hour course on emergency ultrasonography that included 1 hour of instruction and 4 hours of practical training dedicated to echocardiography.[2] Echocardiography was taught in a focused manner, with the primary goal being the detection of a pericardial effusion. All physicians were taught the following conventional cardiac views: parasternal view, apical view, and subcostal view.[6] A combination of these views using the long axis, short axis, or 4-chamber plane was used by the emergency physician for the echocardiographic examination.

All studies were recorded on videotape or thermal paper, and special data collection forms were completed. The indication and presence or absence of a pericardial effusion were noted. Echocardiograms were subsequently reviewed by a single echocardiographer from the Department of Cardiology in a blinded fashion.

Sensitivity, specificity, positive and negative predictive values, overall accuracy, and 95% confidence intervals (CIs) were calculated using the F-distribution. SAS version 6.12 (SAS, Cary, NC) software was used for statistical analysis. Technically inadequate examinations were defined as images with poor image quality such that the presence or absence of a pericardial effusion could not be discerned; these studies were excluded from analysis.

RESULTS

A total of 515 echocardiographic examinations were completed; of these, 478 (93%) examinations were considered technically adequate. Breakdown by clinical indication and final result is shown in Table 1. The majority of examinations were performed for congestive heart failure, followed by blunt chest injury and patients with suspected pericarditis. A total of 103 pericardial effusions were detected. The overall sensitivity was 96% (95% CI 90.4% to 98.9%), and specificity was 98% (95% CI 95.8% to 99.1%). Positive predictive value was 92.5% (95% CI 85.8% to 96.7%), and negative predictive value was 98.9% (95% CI 97.3% to 99.7%). Overall accuracy was excellent at 97.5% (95% CI 95.7% to 98.7%) (Table 2). Table 3 details the study results according to individual indication.

DISCUSSION

Bedside echocardiography allows rapid, noninvasive diagnosis of pericardial effusions and acute pericardial tamponade.[7] Physical examination findings such as Beck's triad, although commonly emphasized, are notoriously unreliable and do not have a definitive role in modern medicine.[8,9] Bedside 2-dimensional echocardiography is the standard for the acute evaluation of pericardial effusions; however, 24-hour echocardiography services are not commonly available in hospitals in the United States. Fortunately, this void in emergency ultrasonographic capability is increasingly being filled by ultrasonography performed by emergency physicians.[10]

Previous emergency echocardiography research has focused primarily on the trauma patient. Bedside echocardiography has an established role in the acute evaluation of patients with penetrating precordial trauma and has been shown to improve outcome in patients with penetrating heart injuries.[11-16] Multiple studies have demonstrated its use in the noninvasive evaluation of cardiac trauma compared with subxiphoid pericardiotomy or thoracotomy. Unfortunately, although echocardiography is being performed by surgeons with increasing frequency at many trauma centers, many of these studies only include echocardiographic studies performed by echocardiographers or cardiologists.[4,12,13,15,17]

Although many studies address ultrasonography performed by emergency physicians, few studies have focused on echocardiography for the evaluation of pericardial effusions. In 1989, Mayron et al[18] evaluated bedside echocardiography in 156 patients, including those with nonperfusing cardiac rhythms, hypotension, and chest trauma. In this study, emergency physicians were trained during a 4-hour ultrasonography course. They detected 7 acute pericardial effusions and felt that patient care had been enhanced in these cases. In 1995, Ma et al[19] reported 245 trauma ultrasonographic images that included a subcostal view of the heart. All emergency physicians had 10 hours of training and 15 to 20 proctored examinations before the study. Heart injuries were uncommon, and they had 6 true-positive and 1 false-positive pericardial examinations. In our study, more than 515 patients at high risk were evaluated, and 103 pericardial effusions were detected. Overall accuracy of 97.5% was excellent, with a clinically comfortable CI. To our knowledge, this is the largest study in echocardiography performed by emergency physicians.

The detection of a pericardial effusion is a relatively straightforward finding and is easily recognized as an anechoic area surrounding the heart within the pericardium (Figure 2).[1,20] Although many studies, training courses, and the focused abdominal sonography for trauma (FAST) examination concentrate on the subcostal

Table 1.
Indications and echocardiographer overread of echocardiograms performed by emergency physicians.

Indication	Effusion Present	Effusion Absent	Total
Unexplained hypotension or dyspnea	14	35	49
Cancer with chest pain or dyspnea	10	18	28
Congestive heart failure/enlarged cardiac silhouette	30	82	112
Blunt chest injury	1	72	73
Penetrating chest injury	8	56	64
Uremia with chest pain or dyspnea	18	29	47
Pericarditis	12	65	77
SLE with chest pain or dyspnea	8	11	19
Other	2	7	9
Total	103	375	478

SLE, Systemic lupus erythematosus.

Table 2.
Overall echocardiographic performance.

	Comparative Standard		
Predicted	**Positive**	**Negative**	**Total**
Positive	99	8	107
Negative	4	367	371
Total	103	375	478

Sensitivity: 96.0% (95% CI 90.4% to 98.9%)
Specificity: 98.0% (95% CI 95.8% to 99.1%)
Positive predictive value: 92.5% (95% CI 85.8% to 96.7%)
Negative predictive value: 98.9% (95% CI 97.3% to 99.7%)
Accuracy: 97.5% (95% CI 95.7% to 98.7%)

view of the heart, we taught and included the parasternal and apical views in our training courses. Because the acoustic windows of the heart are small and sometimes difficult to locate, we felt that a multiple-view approach would yield better results. Obesity, emphysema, and agitation all make echocardiography more difficult; therefore, additional acoustic windows can be beneficial in such cases. In addition, the parasternal view can easily distinguish between pleural and pericardial fluid collections in confusing cases.[20]

Although chest trauma was a common indication, only 9 positive effusions were noted in our study. Other important high-risk presentations were included to better represent a general emergency population and were significantly revealing. We found that chronic congestive heart failure or uremia with an enlarged cardiac silhouette was a common reason for patients to have a pericardial effusion. In addition, patients with malignancies, unexplained hypotension, or dyspnea also commonly had effusions. Although our study was not designed to examine this, we believe that knowledge of these nontraumatic pericardial effusions can contribute to patient care by changing diagnostic impressions, providing alternate therapy, and modifying the level and accuracy of admission. Although we did not examine for echocardiographic signs of tamponade, the finding of a large pericardial effusion will also

Table 3.
Study results according to indication.

Result	Unexplained Hypotension	Cancer	Congestive Heart Failure	Blunt Chest Trauma	Penetrating Chest Trauma	Uremia	Pericarditis	Systemic Lupus Erythematosis	Other
TP	14	10	28	1	8	17	11	8	2
TN	35	18	79	72	56	27	63	11	6
FP	0	0	3	0	0	2	2	0	1
FN	0	0	2	0	0	1	1	0	0
Totals	49	28	112	73	64	47	77	19	9
Sensitivity (95% CI)	100 (80.7–100)	100 (74.1–100)	93 (77.9–99.2)	100 (5.0–100)	100 (68.8–100)	94 (72.7–99.9)	92 (61.5–99.8)	100 (68.8–100)	100 (22.4–100)
Specificity (95% CI)	100 (91.8–100)	100 (84.7–100)	96 (89.7–99.2)	100 (95.9–100)	100 (68.8–100)	93 (77.2–99.2)	97 (89.3–99.6)	100 (76.2–100)	85.7 (42.1–99.6)
PPV (95% CI)	100 (80.7–100)	100 (74.1–100)	90.3 (74.2–98.0)	100 (5.0–100)	100 (68.8–100)	89.5 (66.9–98.7)	84.6 (54.6–98.1)	100 (68.8–100)	66.7 (9.4–99.2)
NPV (95% CI)	100 (91.8–100)	100 (84.7–100)	97.5 (91.4–99.7)	100 (95.9–100)	100 (68.8–100)	96.4 (81.7–99.9)	98.4 (91.6–100)	100 (76.2–100)	100 (60.7–100)
Accuracy (95% CI)	100 (94.1–100)	100 (89.9–100)	95.5 (89.9–98.5)	100 (96.0–100)	100 (95.4–100)	93.6 (82.5–98.7)	96.1 (89.0–99.2)	100 (85.4–100)	88.9 (51.7–99.7)

TP, True-positive; **TN,** true-negative; **FP,** false-positive; **FN,** false-negative; **PPV,** positive predictive value; **NPV,** negative predictive value.

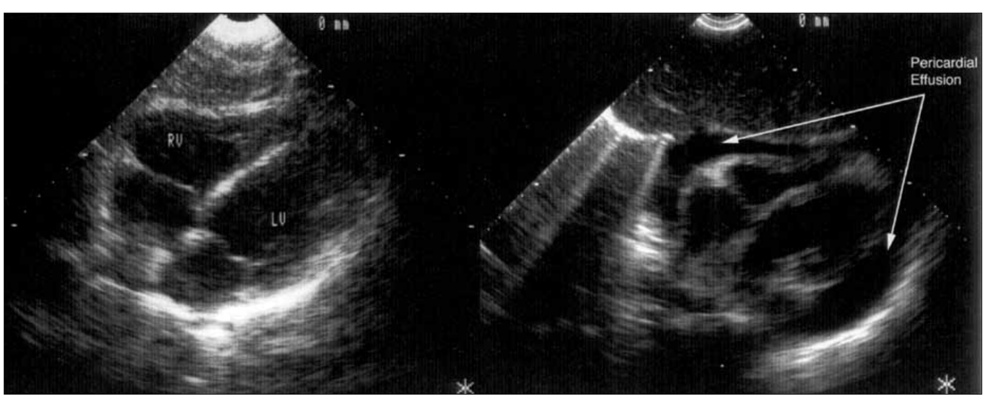

Figure 2.
Echocardiogram images in the 4-chamber plane using the subcostal window. Normal examination is on the left and a positive pericardial effusion is on the right. ***RV****, Right ventricle;* ***LV****, left ventricle.*

allow the emergency physician to consider the diagnosis of cardiac tamponade before hemodynamic changes are present in the patient.

Training remains a contentious issue in ultrasonography.[21] In 1994, the Society for Academic Emergency Medicine published a model curriculum for emergency physician training in ultrasonography.[22] This curriculum recommended a total of 40 hours of education and 150 ultrasonography examinations for training in the primary indications of emergency ultrasonography. A recent position paper by the American Society of Echocardiography and the American College of Cardiology challenges this emergency medicine model curriculum.[23] In their 3-tier training guideline, they recommend a minimum of 150 cardiac ultrasonography examinations with 3 months of formal training. Even with this training, they write, "only in situations of dire emergency should the echocardiography laboratory extender function alone to provide diagnostic information for clinical decisions." These recommendations are consensus rather than evidence based and, unfortunately, do not address solutions for emergency patients who arrive 24 hours a day. Previous work has shown that emergency physicians can be taught focused bedside ultrasonography, and, in this study, we have demonstrated that trained emergency physicians can accurately detect pericardial effusions.[2,24,25]

Although this study focused on the acute evaluation of pericardial effusions, bedside echocardiography can provide other valuable information. With experience, findings of the physiologic characteristics of tamponade, including diastolic right ventricular collapse and inferior vena cava plethora, can be learned.[9] Other important emergency indications include the confirmation of electromechanical dissociation, ultrasonographically guided pericardiocentesis, pacemaker placement assessment, and segmental wall motion abnormalities.[26-30] Noninvasive cardiologists routinely use echocardiography for valvular dysfunction, intracardiac shunts, ventricular contraction, masses, and thrombi, as well as for aortic evaluation.[31] These comprehensive indications require more extensive training and practice, but it is foreseeable that emergency physicians may explore some of these indications in the future.

One limitation of this study was that it was performed at a training program with a high level of sophistication in ultrasonography. All residents receive an introductory 2-day course in ultrasonography in their first year of training; this foundation is built on during the 3-year training program. With natural training inconsistencies between departments and programs, it is not certain that these results would be replicated. In addition, we focused on known high-risk populations to demonstrate emergency physician skill in echocardiography, and thus more subtle effusions seen in other disease processes may not be as consistently detected. In addition, 7% of our studies were deemed to be inadequate for review. This may represent problems with image capture or echocardiographic technique; therefore, future work should examine ways to reduce this.

In summary, in patients in whom an adequate scan can be obtained, emergency physicians can reliably perform focused bedside echocardiography for the detection of pericardial effusions in emergency patients at high risk. Emergency training programs and departments should incorporate this important diagnostic tool into their clinical practice.

Author contributions: DPM, RJH, and SOH conceived and designed the study. RJH wrote the protocol and obtained IRB approval. KM helped collect data, and KM and SOH completed data analysis. DPM drafted the manuscript and all authors contributed to its revision. DPM takes responsibility for the paper as a whole.

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