JACC Vol. 30, No. 3
September 1997:627–32

Dobutamine Stress Tele-Echocardiography for Evaluation of Emergency Department Patients With Chest Pain

JAMES A. TRIPPI, MD, FACC, KAMTHORN S. LEE, MD, FACC, GREG KOPP, RDCS, DAVID R. NELSON, MS, KING G. YEE, MD, FACC, WILLIAM H. CORDELL, MD

Indianapolis, Indiana

Objectives. **The practicality and accuracy of dobutamine stress tele-echocardiography (DSTE) were assessed in patients presenting to the emergency department with chest pain.**

Background. **Many patients evaluated for chest pain in the emergency department (ED) are admitted to the hospital needlessly because of the difficulty in differentiating noncardiac chest pain from myocardial ischemia.**

Methods. **One hundred sixty-three patients with no evidence of myocardial infarction on initial blood studies or the electrocardiogram who were recommended for hospital admission to rule out myocardial infarction or myocardial ischemia were enrolled in this four-phase study. Rest echocardiography was performed in the ED, and the images were transmitted to a cardiologist for interpretation. If the results were normal, DSTE was then administered by a trained nurse. In the first three phases, all patients were admitted for observation regardless of the results of DSTE. In the fourth phase, those having normal DSTE results were able to be released.**

Results. **The test was completed within an average of 5.4 h of presentation to the ED. The sensitivity and specificity of DSTE versus clinical and cardiac catheterization findings were 89.5% and 88.9%, respectively, with a negative predictive value for DSTE of 98.5%. Patients experienced frequent mild side effects (54.7%), but few (6.3%) caused the test to be discontinued prematurely. In phase 4 of the study, 72% of those slated for hospital admission because of cardiac risk factors and chest pain suggesting myocardial ischemia were discharged after normal DSTE results.**

Conclusions. **The use of DSTE in the evaluation of patients presenting with chest pain may improve screening for those who can be safely released from the ED.**

(J Am Coll Cardiol 1997;30:627–32)

Each year ~4 million patients present to U.S. emergency departments (EDs) with complaints of chest pain (1). Because of the difficulty in differentiating noncardiac chest pain from myocardial infarction or ischemia (2), and because of the malpractice risk of discharging a patient with an undiagnosed dangerous cardiac condition (3), patients are often admitted to the hospital.

Numerous methods have been proposed to evaluate patients with chest pain in the ED (4,5). Blood tests (6) are used to diagnose myocardial infarction. Chest pain units for patient observation (7–9) and testing involving rest nuclear imaging (10–13), rest echocardiographic imaging (14–18) and treadmill stress testing (19,20) have all been described.

The use of dobutamine stress echocardiography (21–24) in the ED for chest pain evaluation offers many potential advantages, including ease of administration, patient tolerance (25,26), accuracy comparable to other stress studies (27–30) and proven applicability as a tool for risk stratification (31,32). In the ED, pharmacologic stress testing has advantages over exercise testing by not introducing the noise or space requirements of a treadmill; nor does pharmacologic stress testing require the patient to cooperate and perform strenuous exercise when there is often high anxiety. Also, because intravenous access has already been established on entry into the ED, the invasive nature of pharmacologic stress testing is not objectionable.

To perform remote interpretation of digital echocardiograms, images can be transmitted over standard telephone (33,34) or data lines (35). We previously demonstrated that echocardiographic telemedicine (*tele-echocardiography*) for emergencies can provide rapid, 24-h consultation (36) and that dobutamine stress tele-echocardiography (DSTE) in the ED is feasible (37). In the present study, we sought to evaluate the practicality and accuracy of DSTE in the ED as a screening tool for patients presenting with chest pain.

Methods

Patient enrollment in four phases. Adult patients with chest pain requiring admission for possible myocardial infarc-

From the Department of Cardiology, Center for Health Services Research and Emergency Medicine and Trauma Center, Methodist Hospital of Indiana, Indianapolis, Indiana. This project was supported in part by grants from The Showalter Fund and MetroHealth, Indianapolis, Indiana. This study was presented in part at the 68th Annual Scientific Sessions of the American Heart Association, Anaheim, California, November 1995 and the Seventh Annual Scientific Sessions of the American Society of Echocardiography, Chicago, Illinois, June 1996.

Manuscript received January 14, 1997; revised manuscript received May 21, 1997, accepted May 30, 1997.

Address for correspondence: Dr. James Trippi, Department of Cardiology, 1801 North Senate Avenue, MPC-2, Methodist Hospital of Indiana, Indianapolis, Indiana 46202. E-mail: SXFM24A@Prodigy.com.

Published by Elsevier Science Inc.

0735-1097/97/$17.00
PII S0735-1097(97)00229-5

Abbreviations and Acronyms

CK = creatine kinase
DSTE = dobutamine stress tele-echocardiography (tele-echocardiographic)
ECG = electrocardiogram, electrocardiographic
ED = emergency department

tion or ischemia in the judgment of the emergency physician were eligible for study entry. We gradually implemented testing in a four-phase study (Table 1).

In *phase 1*, patients with risk factors but no history of coronary artery disease, normal electrocardiographic (ECG) results and normal initial creatine kinase (CK) (<190 U/liter for men, <170 U/liter for women [Boehringer Mannheim Hitachi]) and MB fraction values (<5 relative index [ACS immunoassay, Ciba Corning]) who had chest pain that had resolved underwent DSTE in the ED under direct observation by cardiology staff members.

During *phase 2*, similarly identified patients underwent DSTE administered by a nurse and a cardiac sonographer in the ED, with the cardiologist (V.T., K.L., K.Y.) available by telephone.

Phase 3 selection was less restrictive, and patients with no past or present evidence of myocardial infarction by history, CK values or nondiagnostic ECG results were enrolled. Regardless of the DSTE interpretation, all patients in phases 1 to 3 were admitted to the hospital for at least 12 h of observation.

Finally, in *phase 4*, enrollment criteria allowed the participation of patients with minimal residual chest pain (≤2 on a pain intensity scale of 10), nondiagnostic ECG results and mildly elevated initial CK (<400 U/liter) but normal MB fraction values. Patients showing no evidence of myocardial infarction or ischemia on blood studies, ECG, rest echocardiogram and DSTE could be released directly from the ED.

Patients were screened for exclusion criteria by a cardiovascular research nurse who obtained informed consent. Testing was performed at the patient's bedside in the Emergency Medicine and Trauma Center of Methodist Hospital of Indiana. The study was approved by the Institutional review board.

Personnel. Testing was performed by experienced cardiovascular research nurses and cardiac sonographers, which is routine at our institution. Emergency physicians were immediately available and made all decisions regarding admission. One of three cardiologists was available by telephone during the procedure and interpreted the tele-echocardiograms and ECGs.

Procedures. Enrolled patients first had their ECG and rest digitized eight-frame cine-loop quad screen echocardiogram transmitted to the off-site cardiologist's laptop computer-receiving station (Review Software for Windows, TomTec), as previously described (34,36,37). Left ventricular segmental wall motion abnormalities or generalized hypokinesia was recognized by decreased myocardial thickening and systolic motion. If the rest tele-echocardiographic results were considered normal by the cardiologist, administration of dobutamine was authorized; otherwise, the patient was admitted for observation without undergoing pharmacologic stress.

Dobutamine HCI mixed at 1 mg/ml was administered in 3-min stages at 5-, 10-, 20-, 40- and 50-g/kg body weight per min rates, as is customary at our institution. During each stage, symptoms, blood pressure, 12-lead ECG and echocardiogram were recorded. The test was terminated when heart rate rose to 85% of age-predicted maximum (220 beats/min minus age) or 0.5 of mg intravenous atropine was administered and repeated after 1 min. DSTE was discontinued for the usual end points per nursing protocol (25).

After interpretation of the peak stress images, a preliminary DSTE report was transmitted to the ED by the cardiologist. The test was later interpreted in the conventional manner using videotape and digitized images at the echocardiography workstation by a cardiologist who had no knowledge of the telemedicine report.

Follow-up protocol. Patients in phase 4 who were discharged from the ED received follow-up telephone calls by a

Table 1. Dobutamine Stress Tele-Echocardiography in Emergency Department

	Exclusion Criterion	ECG Findings	Supervision	Disposition
Phase 1 (10 pts)	CK >170 U/liter; any cardiac history; residual chest pain; pt able to be released; abnormalities on rest echo	Normal	On-site	All admitted
Phase 2 (27 pts)	As above	Normal	Telemed	All admitted
Phase 3 (51 pts)	CK >170 U/liter; only exclude MI history; CHF or LV dysfunction; pt able to be released; residual chest pain; abnormalities on rest echo	Only exclude MI	Telemed	All admitted
Phase 4 (75 pts)	CK >170 U/liter; only exclude MI history; CHF or LV dysfunction; pt able to be released without normal DSTE results; residual chest pain >2 on 10-pt scale; abnormalities on rest echo	Only exclude MI	Telemed	Pts with abnormalities admitted; pts with normal DSTE results discharged

CHF = congestive heart failure; CK = creatine kinase; DSTE = dobutamine stress tele-echocardiographic, ECG = electrocardiographic; echo = echocardiography; LV = left ventricular; MI = myocardial infarction; pt = patient; Telemed = telemedicine.

registered nurse or physician at 1 week, 1 month and 3 months. Patients who were admitted were called at 3 months after discharge. When telephone contact could not be made, survey sheets were mailed, cardiac catheterization data were obtained, or the patient's physician completed survey information from recent visits. Telephone contact or mailed survey response was successful in 154 patients; another 3 underwent cardiac catheterization, for a cumulative follow-up rate of 96.3%. The Indiana State Vital Records Department reports no record of death for five patients lost to follow-up. The remaining patient lost to follow-up left the country and could not be located.

Statistical methods. Because conventional interpretation of dobutamine stress echocardiography is not considered definitive for myocardial infarction or ischemia, agreement between tele-echocardiography and conventional echocardiographic interpretation was evaluated with the kappa statistic (expressed with 95% confidence intervals). Results from clinical outcome evaluation were used to quantify the predictive value (also expressed with 95% confidence intervals) of the tele-echocardiographic method. Overall accuracy (defined as the number of correct clinical diagnoses divided by the number of diagnoses) was compared with the McNemar test to determine whether conventional and tele-echocardiographic interpretations differed significantly. Logistic regression was used to determine whether DSTE and other tests for ischemia significantly predicted clinical outcome. Mean values are reported as mean ± SD. All calculations utilized software PC-SAS 6.10.

Results

Patient profile and pretest probability of coronary atherosclerosis. From June 1994 through January 1996, a total of 173 patients were screened; the first 26 patients were described in our feasibility study (38). Ten patients were excluded from analysis because of refusal to participate after giving consent (n = 4), technically inadequate echocardiograms (n = 5) and return of chest pain (n = 1), yielding 163 enrolled patients (mean age 49.8 ± 11.6 years, range 19 to 94; 85 men, 78 women). Risk factors for coronary artery disease included hypertension, with rest systolic blood pressure >140 mm Hg or use of antihypertensive agents (n = 61), hypercholesterolemia >200 mg/dl (n = 47), current tobacco use (n = 50) and diabetes mellitus (n = 8).

Pretest probability for significant coronary artery disease averaged 45.4% ± 26.3% by the method of Diamond and Forrester (38) and 39.4% ± 27.7% by the method of Pryor et al. (39).

Time periods. After-hours testing requests occurred during the evenings (n = 40) and weekends (n = 37). Only 16 studies (9.8%) were requested during nighttime hours (between 11 PM and 6 AM). Overall, 93 ED dobutamine stress echocardiograms (57.1%) were requested after regular hours or on weekends.

The average time from the onset of chest pain until ED presentation was 6.5 ± 17.5 h. The time from ED arrival until the dobutamine stress test was requested was 2.9 ± 1.8 h. The time from request until receipt of the telemedicine report was 2.5 ± 1.1 h.

Table 2. Agreement Between Dobutamine Stress Tele-Echocardiography and Conventional Interpretation and Predictive Measures of Tele-Echocardiography With Clinical Outcome

	Tele-Echocardiographic Interpretation	
	Normal	Abnormal
Conventional echo interpretation*		
Normal	127	8
Abnormal	3	25
Clinical outcome†		
Normal	128	16
Abnormal	2	17

*Agreement between conventional workstation and tele-echocardiographic (echo) interpretation of dobutamine stress images: kappa 0.78 (95% confidence interval [CI] 0.65 to 0.90). †Relation between tele-echocardiographic interpretation and clinical outcome (from cardiac catheterization data, follow-up survey and clinical course): sensitivity 89.5% (95% CI 67% to 99%), specificity 88.9% (95% CI 85% to 92%), negative predictive value 98.5% (95% CI 95% to 99%), positive predictive value 51.5% (95% CI 50% to 85%) and overall accuracy 89.0% (95% CI 87% to 95%).

Stress test results and accuracy. DSTE was administered in 139 eligible patients (85.3%). In 24 patients, rest tele-echocardiography showed left ventricular wall motion abnormalities that precluded administration of pharmacologic stress.

Agreement between conventional and tele-echocardiographic interpretations was significant (kappa 0.78, 95% confidence interval [CI] 0.65 to 0.90). None of the three negative telemedicine/positive conventional interpretations were found to have clinical evidence of myocardial ischemia on follow-up.

A final clinical diagnosis was obtained from cardiac catheterization findings, telephone survey or contact with the primary physician at a mean of 3.03 months of follow-up. Of 163 patients undergoing echocardiographic evaluation, 6 (3.7%) were found to have clinical evidence of myocardial infarction, with a delayed rise of CK or MB levels; 12 had coronary artery disease (>50% coronary artery lumen diameter reduction) on cardiac catheterization; 1 had persistent typical angina pectoris; 4 had abnormal nuclear stress test results; and 3 had generalized left ventricular systolic dysfunction diagnosed as myocarditis or cardiomyopathy. When the tele-echocardiographic interpretation was compared with final clinical diagnosis, a sensitivity of 89.5% (95% CI 67% to 99%), specificity of 88.9% (95% CI 85% to 92%), negative predictive value of 98.5% (95% CI 95% to 99%), positive predictive value of 51.5% (95% CI 50% to 85%) and overall accuracy of 89.0% (95% CI 87% to 95%) were obtained (Table 2). By comparison, conventional interpretation had a sensitivity of 73.3% (95% CI 49% to 91%), specificity of 90.7% (95% CI 85% to 95%) and overall accuracy of 88.8% (95% CI 84% to 94%). The overall accuracy of conventional and tele-echocardiographic interpretations did not differ significantly (p = 0.24).

Table 3. Dobutamine Stress Tele-Echocardiography Versus Other Tests for Clinical Heart Disease

	Clinical Evidence of MI/CAD/LV Dysfunction*		
	Yes	No	p Value†
Pretest probability (Diamond and Forrester [38])	72.0 ± 25.7%	42.1 ± 24.3%	0.59‡
Pretest probability (Pryor et al. [39])	69.1 ± 25.5%	35.7 ± 25.7%	0.07‡
Nonspecific ECG abnormalities	11/19 (57.8%)	61/144 (42.4%)	0.79‡
DSTE-induced chest pain	5/19 (26.3%)	41/130 (31.5%)§	0.37‡
DSTE abnormalities	17/19 (89.5%)	15/130 (11.5%)	<0.001

*Sensitivities for different criteria in those with and without clinical evidence of coronary heart disease or left ventricular wall motion abnormalities. †Logistic regression analysis. ‡Not significant. §Because of technically indistinct or falsely abnormal results on rest echocardiograms, only 130 of 144 patients with no clinical heart disease underwent dobutamine stress tele-echocardiography. CAD = coronary artery disease; other abbreviations as in Table 1.

No cardiovascular deaths occurred during follow-up. Ten of 19 patients with clinical heart disease had rest wall motion abnormalities; 7 had stress-induced wall motion abnormalities. Two false negative interpretations occurred by echocardiography (both telemedicine and conventional interpretations). A 66-year old woman with chest pain was admitted for 24-h observation during phase 3 after a normal test interpretation. She was readmitted 1 week later with an inferior myocardial infarction. A 47-year old man in phase 4 was released from the ED with a normal dobutamine stress tele-echocardiographic interpretation. Three months later, persistent chest pain was evaluated by catheterization and showed significant left anterior descending coronary artery disease.

Rest or stress tele-echocardiographic abnormalities were more sensitive and showed greater overall accuracy than rest ECG abnormalities, stress-induced chest pain or pretest probability, or any combination of these variables (Table 3).

Stress study complications. Seventy-six patients (54.7%) reported symptoms during stress testing. Chest pain (45 [32.4%] of 139), nausea (22 [15.8%] of 139), dyspnea (3 [2.1%] of 139) and nonspecific symptoms (6 [4.3%] of 139) were the most common complaints. Premature ventricular contractions were reported in 6 (4.3%) of 139 patients. Symptoms or arrhythmias caused the study to be terminated prematurely in 9 (6.3%) of 139 patients. No symptoms or arrhythmias lasted >10 min or required special treatments. There were no instances in which the test was terminated prematurely because of severe wall motion abnormalities recognized by the sonographer. Of those patients contacted in the follow-up survey, 41 recalled having symptoms during pharmacologic stress, but only 11 patients (7.0%) stated that they would not undergo DSTE if needed in the future.

Subsequent testing. Other noninvasive tests were requested after ED dobutamine stress echocardiography in 25 instances. In six patients with abnormal results on dobutamine stress echocardiography, subsequent noninvasive study results were normal.

Cardiac catheterization was performed in 21 patients during the same hospital stay and in an additional 5 (15.9%) during a later hospital admission. Coronary artery disease (>50% lumen diameter obstruction) or left ventricular systolic dysfunction was found in 17 patients (65.3%) undergoing cardiac catheterization.

ED discharges. During phases 1 to 3, 67 (67.7%) of 99 patients had normal creatine CK-MB fraction levels, nondiagnostic ECG findings and normal results on dobutamine stress echocardiography, yet all were admitted according to protocol. During phase 4, dobutamine stress results were normal in 58 patients. Nevertheless, clinicians admitted four of these patients for observation; none of those admitted with normal DSTE results were found to have myocardial infarction or evidence of myocardial ischemia on follow-up. ED discharge was achieved in 54 patients (72.0%) during phase 4.

Discussion

Personnel responsibility and experience. Cardiac sonographers who are competent and skilled in stress echocardiography can perform DSTE. They must be familiar with digitizing echocardiograms and transmission. Most important, cardiac sonographers must be willing to respond to emergency calls.

Nurses can safely administer this test alone under protocol direction (40). Training, direction and support by cardiologists and emergency physicians are essential.

A background in stress echocardiography prepares a cardiologist to interpret DSTE results. In our own physicians, added confidence came from our experience in emergency tele-echocardiography. Similarly, we gained experience during phases 1 to 3, when all patients were admitted regardless of the telemedical interpretation.

Rest and stress echocardiography in the ED. It is essential that a cardiologist interpret the rest echocardiogram before administration of pharmacologic stress in assessing acute chest pain. Lack of regional wall motion abnormalities on tele-echocardiography indicates the absence of infarction or severe ischemia and obviates a prolonged observation period before stress administration. With tele-echocardiography, rapid interpretation of rest echocardiograms and ECGs allowed stress testing to be performed within 3 h of presentation to the ED.

It is possible to perform dobutamine stress echocardiogra-

phy in the ED without telemedicine by having a cardiologist physically present. However, because the majority of these studies were requested during evenings, nights and weekends, monitoring dobutamine stress echocardiography in the ED without telemedicine would prove a substantial burden for cardiologists or incur prolonged waiting periods for the patients. On completion of DSTE, a printed test report was present in the ED within a mean of 5.4 h. Diagnosis of myocardial infarction or ischemia by blood tests, ECG, observation and stress testing usually takes between 12 and 36 h.

The sensitivity (89.5%) and specificity (88.9%) of DSTE was similar to previously reported values (21–24). Of the 17 patients with clinical heart disease whose tele-echocardiograms demonstrated wall motion abnormalities, 10 had abnormalities at rest, and 7 developed left ventricular wall motion abnormalities only after pharmacologic stress. Thus, the addition of stress testing for patients being evaluated in the ED with echocardiography improves diagnostic accuracy over rest imaging alone. Unfavorable results using rest echocardiography in the ED to screen for myocardial infarction have been reported (41). Stress imaging may be essential for proper risk stratification of patients whose chest pain has mostly resolved.

Response to DSTE. Many patients reported side effects or symptoms during DSTE. The incidence (54.7%) of symptoms and side effects was higher than previously reported (25,26). The recent onset of chest pain and the ED environment may have alerted our patients to chest sensations. Even so, 93.0% of patients in follow-up reported that they would repeat the test again if necessary. Also because most side effects and symptoms were minor, premature termination occurred in only 6.3% of stress tests, which is comparable to that in published reports (25,26).

Study limitations. All patients enrolled in the present study were slated for admission to rule out myocardial infarction or unstable myocardial ischemia. Because our patients were enrolled on the basis of the initial testing and judgment of the emergency physician, our sample selection may have been biased. However, the patients enrolled most likely represent the population causing the greatest diagnostic challenge in clinical practice.

Litigation concerns are prominent in emergency medicine when undiagnosed myocardial infarction results in large malpractice awards (3). Therefore, early discharge from the ED after normal DSTE results may raise concern about liability. However, through careful adherence to chest pain protocols and testing, the risk of inadvertent release of patients from the ED with a myocardial infarction or ischemia may be lessened.

Our assessment of clinical outcome relied on telephone survey in most patients. Only a limited number of patients underwent cardiac catheterization, and clinical assessment of coronary artery disease was subjective.

Tele-echocardiographic interpretation of testing had a low positive predictive accuracy (51.5%) compared with that for clinical outcome. This result may be secondary to aggressive interpretation of minor wall motion abnormalities in an attempt to ensure normality of patients being released from the ED. These minor wall motion abnormalities may have been artifactual or temporary or may reflect intermediate coronary artery obstructions without recurrent symptoms.

A recent report (42) suggests that a review of videotape may yield discordant data compared with cine-loop interpretation. However, the report notes that for normal studies with adequate visualization of myocardial segments, videotape review may not be necessary. Our patients who were released from the ED after DSTE all had endocardial segments displaying normal wall motion.

Conclusions. The use of DSTE in the ED enables rapid, 24-h evaluation of patients presenting with chest pain. Implementation of this program appears to be practical in the clinical setting but requires cooperation and commitment on the part of emergency physicians, cardiologists, nurses and sonographers. Normal results on DSTE in the ED may obviate the need for hospital admission in patients presenting with noninfarction chest pain.

We thank the cardiovascular research nurses and cardiac sonographers of Methodist Hospital of Indiana for their support in patient testing. We are indebted to Margaretha Chrapla, RN for compiling data, contacting patients and providing logistic support.

References

1. Graff L, Joseph T, Andelman R, et al. American College of Emergency Physicians information paper: chest pain units in emergency departments—a report from the short-term observation services section. Am J Cardiol 1995;76:1036–9.
2. National Heart Attack Alert Program Coordinating Committee. Emergency department: rapid identification and treatment of patients with acute myocardial infarction. Ann Emerg Med 1994;23:311–29.
3. Karcz A, Holbrook J, Burke MC, et al. Massachusetts emergency medicine closed malpractice claims: 1988–1990. Ann Emerg Med 1993;22:553–9.
4. Roberts R, Kleiman NS. Earlier diagnosis and treatment of acute myocardial infarction necessitates the need for a "new diagnostic mind-set." Circulation 1994;89:872–81.
5. Gibler WB. Chest pain evaluation in the ED: beyond triage. Am J Emerg Med 1994;12:121–2.
6. Young G, Green T. The role of single ECG, creatine kinase, and CKMB in diagnosing patients with acute chest pain. Am J Emerg Med 1993;11:444–9.
7. Gaspoz JM, Lee TH, Cook EF, Weisberg MC, Goldman L. Outcome of patients who were admitted to a new short-stay unit to "rule-out" myocardial infarction. Am J Cardiol 1991;68:145–9.
8. Lee TH, Juarez G, Cook EF, et al. Ruling out acute myocardial infarction: a prospective multicenter validation of a 12-hour strategy for patients at low risk. N Engl J Med 1991;324:1239–46.
9. de Leon AC, Farmer CA, King G, Manternack J, Ritter D. Chest pain evaluation unit: a cost-effective approach for ruling out acute myocardial infarction. South Med J 1989;82:1083–9.
10. Bilodeau L, Theroux P, Gregoire J, Gagnon D, Arsenault A. Technetium-99m sestamibi tomography in patients with spontaneous chest pain: correlations with clinical, electrocardiographic and angiographic findings. J Am Coll Cardiol 1991;18:1684–91.
11. Varetto T, Cantalupi D, Altieri A, Orlandi C. Emergency room technetium-99m sestamibi imaging to rule out acute myocardial ischemic events in patients with nondiagnostic ECGs. J Am Coll Cardiol 1993;22:1804–8.
12. Hilton T, Thompson R, Williams H, Saylors R, Fulmer H, Stowers S. Technetium-99m sestamibi myocardial perfusion imaging in the emergency room evaluation of chest pain. J Am Coll Cardiol 1994;23:1016–22.
13. Henneman PL, Mena IG, Rothstein RJ, Garrett KB, Pleyto AS, French WJ. Evaluation of patients with chest pain and nondiagnostic ECG using

thallium-201 myocardial planar imaging and technetium-99m first-pass radionuclide angiography in the emergency department. Ann Emerg Med 1992;21:545–50.
14. Hauser AM. The emerging role of echocardiography in the emergency department. Ann Emerg Med 1989;18:1298–303.
15. Peels CH, Visser CA, Kupper AJ, Visser FC, Roos JP. Usefulness of two-dimensional echocardiography for immediate detection of myocardial ischemia in the emergency room. Am J Cardiol 1990;65:687–91.
16. Sabia P, Abbot RD, Afforrktek A, et al. Importance of two-dimensional echocardiographic assessment of left ventricular systolic function in patients presenting to the emergency room with cardiac-related symptoms. Circulation 1991;84:1615–24.
17. Oh JK, Miller FA, Shub C, Reeder GS, Tajik AJ. Evaluation of acute chest pain syndromes by two-dimensional echocardiography: its potential application in the selection of patients for acute reperfusion therapy. Mayo Clin Proc 1987;62:59–66.
18. Kaul S. Value of echocardiography for the assessment of short- and long-term outcome in patients presenting to the emergency room with cardiac-related symptoms. Cardiovasc Imag 1992;4:61–5.
19. Kerns J, Shaub T, Fontanarosa P. Emergency cardiac stress testing in the evaluation of emergency department patients with atypical chest pain. Ann Emerg Med 1993;22:794–8.
20. Lewis W, Amsterdam E. Utility and safety of immediate exercise testing of low-risk patients admitted to the hospital for suspected acute myocardial infarction. Am J Cardiol 1994;74:987–90.
21. Segar D, Brown S, Sawada S. Ryan T, Feigenbaum H. Dobutamine stress echocardiography: correlation with coronary lesion severity as determined by quantitative angiography. J Am Coll Cardiol 1992;19:1197–202.
22. Marcovitz PA, Armstrong WF. Accuracy of dobutamine stress echocardiography in detecting coronary artery disease. Am J Cardiol 1992;69:1269–73.
23. Marwick T, D'Hondt AM, Baudhuin T, et al. Optimal use of dobutamine stress for the detection and evaluation of coronary artery disease: combination with echocardiography or scintigraphy, or both? J Am Coll Cardiol 1993;22:159–67.
24. McNeil AJ, Fioretti PM, El-Said EM, Salustri A, Forster T, Roelandt JRTC. Enhanced sensitivity for detection of coronary artery disease by addition of atropine to dobutamine stress echocardiography. Am J Cardiol 1992;70: 41–6.
25. Mertes H, Sawada SG, Ryan T, et al. Symptoms, adverse effects, and complications associated with dobutamine stress echocardiography: experience in 1118 patients. Circulation 1993;88:15–9.
26. Fetiveau R, Lanzarini L, Poli A, et al. The side effects and safety of the echo-dobutamine test: the experience of 373 patients. G Ital Cardiol 1995;25:193–201.
27. Armstrong W, O'Donnell J, Dillon J, McHenry P, Morris S, Feigenbaum H. Complementary value of two-dimensional exercise echocardiography to routine treadmill exercise testing. Ann Intern Med 1986;10:531–8.
28. Cohen J, Ottenweller J, George A, Duvvuri S. Comparison of dobutamine and exercise echocardiography for detecting coronary artery disease. Am J Cardiol 1993;72:1226–31.
29. Takeuchi M, Araki M, Nakashima Y, Kuroiwa A. Comparison of dobutamine stress echocardiography and stress thallium-201 single-photon emission computed tomography for detecting coronary artery disease. J Am Soc Echocardiogr 1993;5:593–602.
30. Beleslin B, Ostojic M, Stepanovic J, et al. Stress echocardiography in the detection of myocardial ischemia—head to head comparison of exercise, dobutamine, and dipyridamole tests. Circulation 1994;90:1168–76.
31. Lane RT, Sawada SG, Segar DS, et al. Dobutamine stress echocardiography for assessment of cardiac risk before oncardiac surgery. Am J Cardiol 1991;68:976–7.
32. Eichelberger JP, Schwarz KQ, Black ER, Green RM, Ouriel K. Predictive value of dobutamine echocardiography just before non-cardiac vascular surgery. Am J Cardiol 1993;72:602–7.
33. Sobczyk W, Solinger R, Rees A, Elbl F. Transtelephonic echocardiography: successful use in a tertiary pediatric referral center. J Pediatr 1993;122:84–8.
34. Trippi JA, Lee KS, Kopp G, Kovacs R. Emergency diagnosis on a laptop. Physicians Comput 1995;12:10–7.
35. Fisher JB, Alboliras ET, Berdusis K, Webb CL. Rapid identification of congenital heart disease by transmission of echocardiograms. Am J Heart 1996;131:1225–7.
36. Trippi JA, Lee K, S Kopp G, Nelson D, Kovacs R. Emergency echocardiography telemedicine: an efficient method to provide 24-hour consultative echocardiography. J Am Coll Cardiol 1996;27:1748–52.
37. Trippi JA, Kopp G, Lee KS, et al. The feasibility of dobutamine stress echocardiography in the emergency department with telemedicine interpretation. J Am Soc Echocardiogr 1996;9:113–8.
38. Diamond G, Forrester J. Analysis of probability as an aid in the clinical diagnosis of coronary-artery disease. N Engl J Med 1979;300:1350–8.
39. Pryor D, Harrell F, Lee K, Califf R, Rosati R. Estimating the likelihood of significant coronary artery disease. Am J Med 1983;75:771–80.
40. Bremer ML, Monahan KH, Stussy VL, Miller FA, Pellikka PA. Safety and effectiveness of dobutamine stress echocardiography monitored by RN sonographer [abstract]. J Am Soc Echocardiogr 1996;9:364.
41. Levitt MA, Promes SB, Bullock S, et al. Combined cardiac marker approach with adjunct two-dimensional echocardiography to diagnose acute myocardial infarction in the emergency department. Ann Emerg Med 1996;27:1–7.
42. Attenhofer CH, Pellikka PA, Oh JK, et al. Is review of videotape necessary after review of digitized cine-loop images in stress echocardiography? A prospective study in 306 patients. J Am Soc Echocardiogr 1997;10:179–83.