JACC Vol. 17, No. 3
March 1, 1991:666–9

Stress Echocardiography and the Human Factor: The Importance of Being Expert

EUGENIO PICANO, MD, FABIO LATTANZI, MD, ANDRÉS ORLANDINI, MD,
CECILIA MARINI, MD, ANTONIO L'ABBATE, MD, FACC

Pisa, Italy

The aim of this study was to evaluate how the diagnostic accuracy of a stress echocardiographic procedure, such as a dipyridamole echocardiography test, depends on the specific experience of the physician interpreting the test. Recordings of 50 consecutive dipyridamole echocardiographic tests were selected for the first part of the study. They were analyzed by 20 experienced echocardiographers with different backgrounds in stress echocardiography: 10 beginners (<20 stress studies interpreted with trained staff) and 10 experienced observers (≥100 stress studies performed). Diagnostic accuracy (true positive + true negative/total number of tests) versus the angiographic reference standard (>70% coronary stenosis of at least one major coronary artery) was 62 ± 6% for beginners and 85 ± 3% for experienced observers (p < 0.0001).

In the second part of the study, 10 observers (5 beginners and 5 experienced observers) evaluated 2 different sets of 50 dipyridamole echocardiographic test studies before and after the training of the beginners. Before training, the accuracy of beginners was lower than that of experienced observers (61 ± 7% versus 85 ± 3%; p < 0.001). After training, the accuracy gap was closed (83 ± 3% versus 86 ± 2%; p = NS).

Therefore, interpretation of stress echocardiographic tests by an echocardiographer without specific training severely underestimates the diagnostic potential of this technique. One hundred stress echocardiographic studies are more than adequate to build the individual learning curve and reach the plateau of diagnostic accuracy that the test can yield.

(J Am Coll Cardiol 1991;17:666–9)

Stress echocardiography is being increasingly promulgated as a new diagnostic tool for coronary artery disease. Its low cost, noninvasive nature and availability make echocardiography an attractive option as a cardiac imaging modality to combine with exercise or pharmacologic stimuli (1). However, several issues remain to be solved before widespread community use of stress echocardiography, perhaps the most important of which is the determination of the extent to which it is a procedure that must be performed by experts rather than a "routine" procedure (2,3). Clearly, the bulk of scientific work in stress echocardiography has been done in university hospital laboratories where the experience and expertise of the interpreting physicians are not in question. The dependence of diagnostic accuracy of stress echocardiography on the specific training and expertise of the physician performing and interpreting such tests remains to be established.

The aim of this study was to evaluate how the diagnostic accuracy of a stress echocardiographic procedure, such as the dipyridamole echocardiographic test, depends on the specific experience of the physician interpreting the test. Furthermore, we tried to assess how specific training in stress echocardiography can modify the diagnostic performance of the cardiologist-echocardiographer interpreting the test. This study was therefore performed in two segments: 1) a "horizontal" study in which the diagnostic performance of 20 cardiologist-echocardiographers (10 with and 10 without an established experience in stress echocardiography) were compared; and 2) a "longitudinal" study in which the diagnostic performance of 10 cardiologist-echocardiographers was assessed before and after a period of training in stress echocardiography in our laboratory.

Methods

Study Design

Horizontal study. Twenty observers read and interpreted videotapes of dipyridamole echocardiographic studies. These 20 observers were cardiologists who had completed a full training program in echocardiography (M-mode, two-dimensional and Doppler techniques: "level 3" training) (4). At the beginning of the study, the 20 observers could be allocated into two separate subsets on the basis of a substantially different background in stress echocardiography: "beginners," who had performed and interpreted <20 stress echocardiographic studies with a supervising expert senior staff; and "expert observers," who had performed and

From the C.N.R. Clinical Physiology Institute, University of Pisa, Pisa, Italy. Dr. Orlandini is a visiting fellow from Fundaciòn Emera, Rosario, Argentina. Dr. Marini is a visiting fellow from Clinica Medica I, University of Florence, Italy.

Manuscript received November 20, 1989; revised manuscript received July 11, 1990, accepted October 9, 1990.

Address for reprints: Eugenio Picano, MD, C.N.R., Istituto di Fisiologia Clinica, Via P. Savi, 8, 56100 Pisa, Italy.

0735-1097/91/$3.50

interpreted ≥100 stress echocardiographic studies. The videotape recordings of 50 dipyridamole echocardiographic studies were selected for the first part of the study.

Longitudinal study. Ten observers (five "absolute beginners" and five "expert observers") took part in this section of the protocol. Their diagnostic performance was first evaluated in the 50 dipyridamole echocardiographic studies selected for the "horizontal study" at the beginning of the training period in stress echocardiography for the five absolute beginners. After the training period, consisting of 100 stress echocardiographic studies performed with a supervising expert senior staff, diagnostic performance was again assessed for all 10 observers on a different set of 50 other dipyridamole echocardiographic studies.

Study patients. The first set of recordings was from 50 patients (31 men, 19 women, aged 55 ± 8 years) who had chest pain with effort; of these, 14 had pain only with effort, whereas 36 also had pain at rest. The second set of recordings was from 50 other patients (34 men, 16 women, mean age 54 ± 9 years) who had chest pain with effort; of these, 17 had pain only with effort, whereas 33 also had pain at rest.

As an inclusion criterion, all 100 patients studied by dipyridamole echocardiography had coronary angiography performed within 1 week of the study; this information was necessary to evaluate the diagnostic accuracy of each observer. An exclusion criterion was the presence of regional dyssynergy on the rest echocardiogram. Obviously, in this case, the presence of coronary artery disease is known from the outset, which would bias the reading. Therefore, an initial set of 141 patients was evaluated before selection of the final 100 study patients.

Observers did not know the coronary angiographic results at the time of reading, whereas information on electrocardiographic (ECG) changes and chest pain during the dipyridamole test was available. In this way, the typical clinical situation in which stress echocardiography is employed to answer true diagnostic dilemmas was more closely simulated.

Dipyridamole Echocardiography

Two-dimensional echocardiographic and 12 lead ECG monitoring were performed in combination with dipyridamole infusion (0.56 mg/kg body weight over 4 min, followed by 4 min of no dose and then 0.28 mg/kg over 2 min; the cumulative dose was therefore 0.84 mg/kg during 10 min) (5). Aminophylline (240 mg), which promptly reverses the effect of dipyridamole, was always available. Two-dimensional echocardiograms were continuously performed and intermittently recorded during and up to 10 min after dipyridamole administration.

Regional wall motion analysis. In the baseline studies, all standard echocardiographic views were obtained when possible. During the test, new areas of abnormal wall motion were identified on multiple views by moving the ultrasound transducer through various positions. Segmental anatomy and wall motion were assessed in a qualitative manner, as previously reported (5). Wall motion was graded as normal, hyperkinetic, hypokinetic, akinetic and dyskinetic. A positive test was defined as one showing transient asynergy of contraction that was absent in the baseline examination. In this study, only the judgment with respect to the presence (not the grading) of asynergy was evaluated.

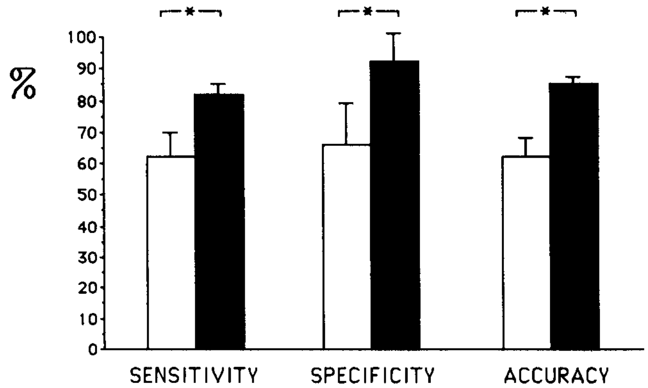

Figure 1. Histograms showing the sensitivity, specificity and diagnostic accuracy for the two groups of observers (beginners [**white bars**] versus experts [**black bars**]) reviewing the same set of 50 videotapes. *$p < 0.0001$.

Angiographic study. All patients underwent selective coronary arteriography performed with either the Judkins or Sones technique. Multiple views of each vessel were filmed. A vessel was considered to have significant obstruction if its diameter was narrowed by ≥70% with respect to the prestenotic segment. Two independent observers who were unaware of echocardiographic and clinical data visually analyzed coronary angiograms for the degree of stenosis in the right, left main, left anterior descending (or diagonal) and left circumflex (or marginal) coronary arteries. When there was disagreement over the degree of stenosis, a third observer reviewed the study and his or her judgment was binding.

Statistical analysis. Sensitivity, specificity and diagnostic accuracy in detecting angiographically assessed coronary artery disease were calculated according to standard definitions (6). Values are expressed as mean values ± SD and differences were tested for significance by means of Student's t test for paired and unpaired values. The required level of significance was $p < 0.05$.

Results

Angiographic study. Of the 50 patients in the first videotape set, 33 had angiographically documented coronary artery disease (15 with single, 14 with double and 4 with triple vessel disease). Of the 50 patients in the second videotape set, 34 had angiographically documented coronary artery disease (17 with single, 13 with double and 4 with triple vessel disease).

Dipyridamole test. *Horizontal study (Fig. 1).* The 10 beginners showed a substantially lower diagnostic accuracy

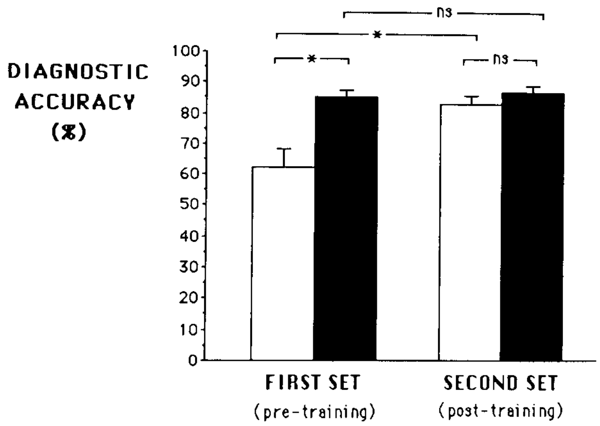

Figure 2. Histograms showing the diagnostic accuracy for the five beginners (**white bars**) and five experts (**black bars**) who reviewed two other sets of 50 videotapes before and after a 6 month training period of 100 studies. *$p < 0.001$.

than that of the 10 experienced observers (62 ± 6% versus 85 ± 3%, $p < 0.0001$). This accuracy loss equally affected sensitivity (62 ± 8% versus 82 ± 4%, $p < 0.0001$) and specificity (66 ± 13% versus 92 ± 9%, $p < 0.0001$). The false positive results occurred more frequently in patients without coronary artery disease who had angina or ECG changes, or both, during the test rather than in those without these nonspecific signs of ischemia (69% versus 31%, $p < 0.01$).

Longitudinal study (Fig. 2). In the first set of videotapes (pretraining situation), the five beginners had a significantly lower diagnostic accuracy than that of the five experienced observers (61 ± 7% versus 85 ± 3%, $p < 0.001$). In the second set of videotapes (posttraining situation), the accuracy gap was closed (83 ± 3% versus 86 ± 2%, p = NS). The diagnostic accuracy for the beginners' group increased significantly ($p < 0.001$) after the training period, but it did not change (p = NS) in the experts group after the same period.

Discussion

Implications of the study. Our data show that 1) extensive expertise in routine echocardiography at rest is necessary but by no means sufficient to adequately interpret stress echocardiographic studies; and 2) the training in stress echocardiography requires no more than 100 stress studies interpreted with a supervising experienced trainer. In our opinion, these data have two practical implications.

First, evaluation of interpretation of stress echocardiographic studies by an echocardiographer without specific training severely underestimates the diagnostic potential of this technique, and absolute beginners in stress echocardiography, even if very experienced in rest echocardiography, are unlikely to solve many diagnostic problems. It is striking that beginners had an average diagnostic accuracy of only 62% in the pretraining reading (that is, a diagnostic performance slightly better than tossing a coin). It is apparent from these data that stress echocardiography should not be performed for diagnostic purposes (and much less for scientific purposes) in a laboratory without established experience in this aspect of ultrasound diagnosis, even when there is a clear-cut clinical indication for this study. This observation is consistent with the belief that, although two-dimensional echocardiography is a nearly ideal technique for imaging myocardial ischemia (7), its widespread acceptance is limited by the subjective analysis of the data and, most important, by the fact that of all aspects of echocardiographic diagnoses, wall motion analysis is perhaps the most difficult and the one that requires the most experience. Of interest, many false-positive results of absolute beginners occurred in patients with chest pain or "ischemic" ECG changes, or both, during dipyridamole infusion. These ancillary markers of ischemia are limited by a very low specificity and can easily mislead the beginner.

The second implication derived from this study is that the learning curve for stress echocardiography requires no more than 100 stress studies interpreted with an experienced supervisor. This training period does not appear to differ substantially from that required to acquire Doppler ultrasound skills by an operator experienced in M-mode and two-dimensional echocardiography (4). It is not surprising that this expansion of the diagnostic use of echocardiography requires a further increase in training but, this obvious fact is frequently forgotten although it might explain some reported inconsistencies on the feasibility and usefulness of stress echocardiographic techniques by different laboratories. Our results emphasize caution to cardiologists who wish to begin using stress echocardiographic testing in their practice.

Limitations of the study. In this study, we dealt with the problem of interpreting a given set of videotapes of dipyridamole echocardiographic studies. The situation can be more complex in the complete assessment of whether stress echocardiography must be performed by experts or can be considered routine examination. A critical factor is image acquisition, which was performed in our studies by an experienced physician who did not take part in the reading sessions. It is certain that complete imaging of the heart under rest conditions and during stress is crucial for the detection of asynergy that is usually transient and regional. However, the basic skills required for imaging the heart under rest conditions are not substantially different from those required for imaging the same heart from the same projections during stress. At least this is true for the stress echocardiographic technique tested in the present study (namely, dipyridamole echocardiography). Intravenous dipyridamole is not available for routine clinical use in the United States (although perhaps it should be) (8) and thus other methods for inducing stress, such as treadmill or bicycle ergometer exercise, are more widely used. Our data obtained with the dipyridamole echocardiographic test can be incorrect for other stresses, such as exercise or postexercise echocardiography, where the quality of ultrasound images can be lessened by excessive hyperventilation, tachycardia or chest wall motion (9).

In this study, significant coronary artery obstruction was diagnosed if ≥70% narrowing of luminal diameter was judged present by visual analysis. Although this criterion was applied consistently to all patients and was independent of the stress echocardiographic results, its appropriateness could be questioned (10). Visual assessment of coronary artery diameter has notably wide confidence limits; it is possible that some lesions that appear to be significant did not in fact cause physiologic regional ischemic dysfunction after intravenous dipyridamole and that other lesions that seemingly were insignificant actually did lead to ischemic dysfunction. It would have been preferable to have used as a standard of reference a technique that defines the presence or absence of regional ischemia, rather than a visual estimate of coronary artery narrowing. Although it probably does not affect the overall finding of our study, this limitation must be acknowledged.

Finally, in this study, no system for digital image acquisition was employed. This would have required additional apparatus and expense, but would allow cine loop display in quad-screen format, which undoubtedly would make the interpretation easier (11). In theory, this might further shorten the time required to complete the learning curve in stress echocardiography.

Conclusions. Stress echocardiography is easy to learn, but a sufficient learning period is required. If there has been no previous exposure to specialized training, the use of stress echocardiography should be postponed.

References

1. Amstrong WF. Echocardiography in coronary artery disease. Prog Cardiovasc Dis 1988;30:267–88.
2. Bairey CN, Rozanski A, Berman DS. Exercise echocardiography: ready or not (editorial)? J Am Coll Cardiol 1988;11:1355–8.
3. Armstrong WF. Exercise echocardiography: ready, willing and able (editorial). J Am Coll Cardiol 1988;11:1359–61.
4. Pearlman AS, Gardin JM, Martin RP, et al. Guidelines for optimal physician training in echocardiography. Am J Cardiol 1987;60:158–63.
5. Picano E, Lattanzi F, Masini M, Distante A, L'Abbate A. High dose dipyridamole echocardiography test in effort angina pectoris. J Am Coll Cardiol 1986;8:848–54.
6. Sheffield LT. Exercise stress test. In: Braunwald E, ed. Heart Disease: A Textbook of Cardiovascular Medicine. Philadelphia: WB Saunders, 1984: 253–75.
7. Mann DL, Gillam LD, Weyman AE. Cross-sectional echocardiographic assessment of regional ventricular performance and myocardial perfusion. Prog Cardiovasc Dis 1986;29:1–52.
8. Beller GA. Dipyridamole-thallium-201 scintigraphy: an excellent alternative to exercise scintigraphy? J Am Coll Cardiol 1989;14:1642–4.
9. Picano E, Lattanzi F, Masini M, Distante A, L'Abbate A. Comparison of high-dose dipyridamole-echocardiography test and exercise 2D echocardiography for diagnosis of coronary artery disease. Am J Cardiol 1987; 59:539–42.
10. Marcus ML, White CW, Kirchner PT. Isn't it time to reevaluate the sensitivity of noninvasive approaches for the diagnosis of coronary artery disease? J Am Coll Cardiol 1986;8:1033–4.
11. Feigenbaum H. Exercise echocardiography. J Am Soc Echo 1988;1: 161–6.