JACC Vol. 29, No. 6
May 1997:1234–40

# Evolution of Dobutamine Echocardiography Protocols and Indications: Safety and Side Effects in 3,011 Studies Over 5 Years

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***Objectives.*** **This study sought to document the safety of dobutamine stress echocardiography as it has evolved at a single center and to define predictors of adverse events.**

***Background.*** **The indications and protocol for dobutamine stress testing have evolved over 5 years of clinical use, but the influence of these changes on the safety and side effects of the test is undefined.**

***Methods.*** **Over 5 years, 3,011 consecutive dobutamine stress studies were performed in 2,871 patients, using an incremental protocol from 5 to 40 μg/kg body weight per min in 3-min stages, followed by atropine or an additional stage with 50 μg/kg per min, if required. Clinical data were gathered prospectively, and hemodynamic and echocardiographic findings were recorded at each stage, including recovery. Dobutamine echocardiography was defined as positive for ischemia in the presence of new or worsening wall motion abnormalities; in the absence of ischemia, failure to attain 85% of age-predicted maximal heart rate was identified as a nondiagnostic result.**

***Results.*** **Studies were performed for risk assessment (70%) and symptom evaluation (30%); over the study period, there was an increment in the use of dobutamine echocardiography for preoperative evaluation. Most tests (n = 2,194 [73%]) were terminated due to attainment of peak dose with achievement of target heart rate (>85% maximal age-predicted heart rate); 455 patients (15%) failed to achieve >85% maximal predicted heart rate despite maximal doses of dobutamine and atropine. The protocol was stopped prematurely in 230 patients (7.6%) because of side effects, including ventricular (n = 27 [0.9%]) and supraventricular rhythm disorders (n = 22 [0.7%]), severe hypertension (n = 24 [0.8%]) and hypotension or left ventricular outflow tract obstruction (n = 112 [3.8%]). Noncardiac symptoms, such as headache, nausea or anxiety, caused early test termination in 45 patients (1.6%). The remaining tests were stopped because of severe chest pain (n = 106 [3.5%]) or severe ischemia by echocardiography (n = 26 [0.9%]). Serious complications occurred in nine patients, including sustained ventricular tachycardia in five, myocardial infarction in one and other conditions in three requiring hospital admission (sustained supraventricular tachycardia, hypotension, suspected myocardial infarction), but neither ventricular fibrillation nor death occurred. Independent predictors of serious complications could not be defined. Over 5 years, higher dose protocols and more frequent use of atropine have raised the number of diagnostic protocols from 59% to 80%, without increasing the incidence of major side effects.**

***Conclusions.*** **Despite the use of more aggressive protocols and alterations of the indications for testing to include sicker patients, major side effects are a rare complication of dobutamine echocardiography.**

**(J Am Coll Cardiol 1997;29:1234–40)**


Since the first reported use of dobutamine as a cardiac stress agent in 1984, this synthetic catecholamine has become increasingly important in pharmacologic stress testing. Initially used as a test for the diagnosis of coronary artery disease in patients unable to exercise (1,2), the indications for dobutamine echocardiography have expanded into risk stratification of patients undergoing vascular surgery (3–6), patients with stable chronic coronary disease (7) or previous myocardial infarction (8,9), as well as the assessment of myocardial viability (10–13). Thus, the test has been applied to progressively more complex, older and higher risk patients as it has been shown to be of prognostic value.

In the context of expanding the indications to include sicker patients and the use of increasingly aggressive protocols, including combination with atropine (14,15), the results of older studies of safety and efficacy may be less applicable (16,17). The only recent study of the safety of dobutamine echocardiography, involving ~2,800 patients at overseas centers, identified serious side effects in 0.5% but enrolled patients generally younger than those usually requiring a pharmacologic stress study in the United States (18). Importantly, that study did not enroll patients undergoing perioperative risk stratification, a group that comprises patients with serious comorbidity, including elderly patients undergoing vascular and orthopedic surgery, those with end-stage renal disease and patients with severe chronic left ventricular dysfunction. Thus, the purpose of the present study was to document the safety and side effects of dobutamine echocardiography over a period

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Manuscript received October 4, 1996; revised manuscript received January 7, 1997, accepted January 23, 1997.

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Published by Elsevier Science Inc.

0735-1097/97/$17.00
PII S0735-1097(97)00039-9

**Abbreviations and Acronyms**

ACE = angiotensin-converting enzyme
ECG = electrocardiogram, electrocardiographic

of 5 years at a single large center. An attempt was made to define predictors of adverse events and show trends in their frequency, in parallel with changes in the dobutamine echocardiographic protocol and indications.

## Methods

**Study population.** Between July 1991 and December 1995, 3,011 consecutive dobutamine echocardiograms were acquired in 2,871 patients (mean [±SD] age 66 ± 12 years, range 19 to 94; 1,688 men [56%]) at our institution. Clinical and hemodynamic data were collected prospectively. Table 1 summarizes the changes in the clinical profile of the study patients. Diabetes mellitus was present in 560 patients (19%), with an increasing prevalence of patients with this diagnosis, and comparable numbers of insulin-dependent (n = 286) and non–insulin-dependent (n = 274) diabetic patients. Many patients had known coronary artery disease, including previous myocardial infarction (n = 476), previous coronary artery bypass graft surgery (n = 417) or coronary angioplasty (n = 241) or were receiving medical therapy, including beta-adrenergic blocking agents (n = 585), angiotensin-converting enzyme inhibitors (n = 636) and diuretic drugs (n = 981).

**Dobutamine–atropine infusion protocol.** Patients were requested to discontinue beta-blockers on the day of the stress test, but other antianginal therapy was not routinely stopped. Before starting the infusion, hemodynamic variables were assessed at rest, and a 12-lead electrocardiogram (ECG) and two-dimensional echocardiogram were also obtained at rest. Dobutamine was then infused, starting at a dose of 5 μg/kg body weight per min, increasing to 10, 20, 30 and 40 μg/kg per min at intervals of 3 min. If <85% maximal age-predicted heart rate was achieved at the end of the standard protocol, and in the absence of contraindications, such as glaucoma or symptoms of prostatic obstruction, atropine (in 0.25-mg boluses to 2 mg) was administered (14) or an additional stage with 50 μg/kg per min of dobutamine was added, or both. The infusion was terminated after the maximal dose of dobutamine was administered or the target heart rate was achieved (end of protocol), or if one of the following developed: severe angina, severe left ventricular outflow tract obstruction (Doppler gradient >65 mm Hg with systolic anterior motion of the mitral valve) or other major side effects (systolic blood pressure decrease >20 mm Hg below baseline and <100 mm Hg, persistent systolic blood pressure increase >220 mm Hg, severe rhythm disorders, severe vagal reaction or other intolerable noncardiac symptoms, including headache or nausea). The target heart rate was used as an end point before attainment of a peak dose <40 μg/kg per min in 321 tests (11%), more commonly in the initial part of this experience.

**ECG and echocardiographic imaging.** A 12-lead ECG and hemodynamic variables were continuously monitored throughout the infusion and at least 6 min into recovery. *Clinical evidence of ischemia* was identified if the patients developed anginal pain or ST segment changes.

Echocardiographic images in the parasternal long- and short-axis and two- and four-chamber views were obtained at rest and at each stage of the test, as well as during recovery (usually 3 min after the end of the infusion). Images at rest, low dose (10 μg/kg per min), prepeak (30 μg/kg per min) and peak dose were digitized and displayed in a quad-screen digital format. Studies were interpreted by at least two observers who had no knowledge of the clinical and ECG data. Regional wall motion scores were obtained at each stage and graded as normal, mild or severely hypokinetic, akinetic or dyskinetic, using a 16-segment model (19). *Echocardiographic evidence of ischemia* was identified if regional function worsened in any segment, except if the basal inferior or septal walls were involved, in which case an adjacent abnormal segment was required (20). Studies were identified as nondiagnostic if the patient attained <85% age-predicted maximal heart rate in the absence of inducible ischemia. Interpretation was attempted in all patients, and although in five the test was nondiagnostic due to poor image quality, no study was terminated for this reason.

**Statistical analysis.** Continuous variables are reported as mean value ± SD and range and compared using analysis of

**Table 1.** Clinical Characteristics of Patients Undergoing Dobutamine Echocardiography, 1991 to 1995

| | 1991–1993 (n = 869) | 1994 (n = 903) | 1995 (n = 1,239) | p Value |
|---|---|---|---|---|
| Age (yr) | 64 ± 12 | 66 ± 12 | 66 ± 12 | 0.0005 |
| Male | 496 (57%) | 510 (57%) | 682 (55%) | 0.62 |
| Diabetes mellitus | 143 (17%) | 136 (15%) | 281 (23%) | < 0.0001 |
| End-stage renal disease | 58 (7%) | 59 (7%) | 133 (11%) | < 0.0001 |
| Atherosclerotic vascular disease | 205 (24%) | 273 (30%) | 410 (33%) | < 0.0001 |
| Therapy | | | | |
| Beta-blockers | 146 (17%) | 166 (18%) | 273 (22%) | 0.007 |
| ACE inhibitors | 150 (17%) | 198 (22%) | 315 (35%) | < 0.0001 |
| Diuretic drugs | 240 (28%) | 309 (34%) | 432 (35%) | 0.001 |

Data presented are mean value ± SD or number (%) of patients.

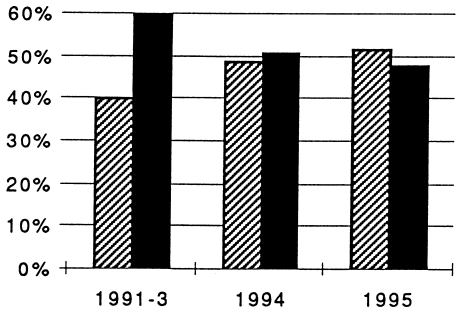


**Figure 1.** Evolution of indications for dobutamine stress echocardiography from 1991 to 1995. **Solid bars** = symptom evaluation; **hatched bars** = risk stratification.

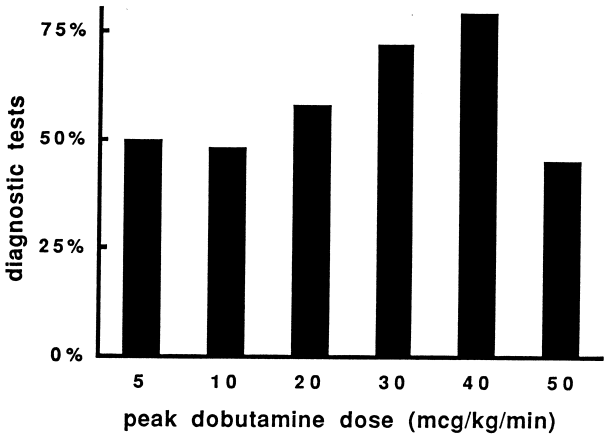


**Figure 2.** Relation between diagnostic test responses and peak dobutamine dose.

variance. Discrete variables were analyzed using the chi-square test; $p < 0.05$ was considered statistically significant.

## Results

**Indications.** The use of dobutamine echocardiography increased substantially from 1991 to 1995 (Table 1). The reasons for performing dobutamine echocardiography rather than an exercise test included inability to exercise because of claudication, orthopedic diseases, advanced age and other medical conditions precluding adequate physical exercise, as well as testing for the identification of viable myocardium. Figure 1 shows the evolution of the use of dobutamine echocardiography from a test used for symptom evaluation to its use for risk stratification.

**Response to dobutamine stress.** The hemodynamic responses to dobutamine stress are shown in Table 2. Over the 5-year period, the mean peak dose of dobutamine given increased from 34.1 to 38.5 μg/kg per min, with a commensurate increase in stress duration from 14 ± 4 to 15 ± 3 min. Atropine was added to the protocol almost three times as often in 1995 (39%) than in earlier years. This addition of atropine led to a significantly higher mean peak heart rate (134 beats/min) and percent of maximal heart rate attained (87%). From 15% to 20% of the tests showed evidence of ischemia.

Figure 2 examines the relation between diagnostic test responses and the peak dose administered during the test. The highest percentage of diagnostic tests was obtained using a peak dose of 40 μg/kg per min. Of the 925 patients who had no ischemia and were below the target heart rate at a dose of 40 μg/kg per min, 220 (mainly with contraindications to atropine) underwent an additional increment of dobutamine (to 50 μg/kg per min), and 98 (45%) finally attained their target heart rate. Of the 935 patients who received atropine because of a suboptimal heart rate response, the target heart rate was achieved in 664 (71%). The mean total dose of dobutamine administered as well as mean stress time were significantly higher in those given atropine (17 ± 2 vs. 14 ± 3 min, 33.5 ± 12.8 vs. 21.8 ± 10.1 mg, respectively, $p < 0.0001$ for both).

Patients treated with beta-blockers achieved a significantly lower peak heart rate (127 ± 20 vs. 134 ± 17 beats/min, $p < 0.0001$) and percent of maximal predicted heart rate (82 ± 13% vs. 87 ± 11%, $p < 0.0001$) than those not treated with beta-blockers, despite the more frequent administration of atropine (57% vs. 25%, $p < 0.0001$). Patients with a rest heart rate <50 beats/min showed a similar trend, achieving target heart rate in only 51% compared with 71% without bradycardia at rest. Of 43 patients with a cardiac pacemaker, only 54% achieved their target heart rate, and 35% of tests required additional increments of dobutamine or atropine, or both.

**Table 2.** Dobutamine Stress Protocol and Hemodynamic Responses in 3,011 Patients Studied Between 1991 and 1995

| | 1991–1993 (n = 869) | 1994 (n = 903) | 1995 (n = 1,239) | p Value |
|---|---|---|---|---|
| Peak dobut dose (mg) | 34 ± 9 | 37 ± 7 | 39 ± 7 | < 0.0001 |
| Atropine | 117 (13.5%) | 308 (34%) | 447 (39%) | < 0.0001 |
| Stress time (min) | 14 ± 4 | 15 ± 3 | 15 ± 3 | < 0.0001 |
| Rest HR (beats/min) | 75 ± 14 | 75 ± 14 | 74 ± 14 | 0.24 |
| Rest SBP (mm Hg) | 148 ± 27 | 147 ± 25 | 149 ± 25 | 0.11 |
| Peak HR (beats/min) | 129 ± 18 | 134 ± 18 | 134 ± 17 | < 0.0001 |
| Max predicted HR% (peak) | 83 ± 12 | 87 ± 12 | 87 ± 10 | < 0.0001 |
| Peak SBP (mm Hg) | 146 ± 35 | 148 ± 36 | 149 ± 25 | 0.07 |
| Ischemia identified | 158 (18%) | 139 (15%) | 247 (20%) | 0.03 |

Data presented are mean value ± SD or number (%) of patients. dobut = dobutamine; HR = heart-rate; SBP = systolic blood pressure.

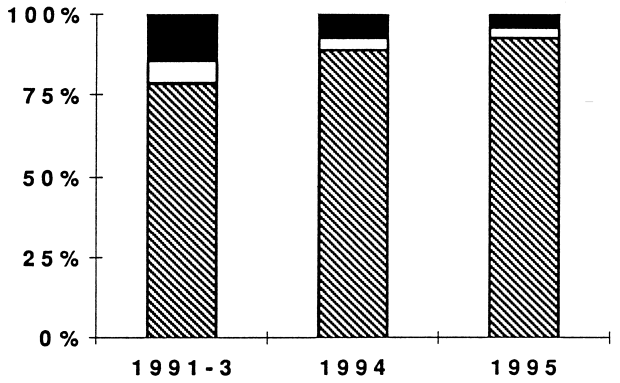


**Figure 3.** Reasons for test termination in 3,011 dobutamine stress echocardiograms obtained from 1991 to 1995. **Solid areas** = side effects; **open areas** = ischemia; **hatched areas** = end of protocol.

**End points of dobutamine stress.** The indications for concluding the test are shown in Figure 3. Side effects led to the premature conclusion of the protocol in 13.8% of the initial cohort, 7.0% of the patients studied in 1994 and 3.7% of those studied in 1995 (Fig. 3). The higher threshold for terminating the test because of side effects was not attended by a greater frequency of serious arrhythmias (Table 3). Medical intervention was required in 275 (9%) of all studies, including nitroglycerin (n = 109 [3.6%]), beta-blockers (n = 106 [3.5%]), calcium channel blocking agents (n = 35 [1.2%]) and saline for hypotension (n = 64 [2.1%]). Other drug therapy included the use of atropine for vagal symptoms (five patients), lidocaine for ventricular tachycardia, adenosine and digoxin for supraventricular tachycardia, dopamine for hypotension and diazepam for anxiety.

Angina occurred in ~25% of patients (n = 748), and its overall incidence did not differ to a meaningful degree over the years. Patients with a history of myocardial infarction were more likely to develop dobutamine-induced angina (29% vs. 24%, $p = 0.02$), as were patients with a history of typical and atypical chest pain (41% vs. 19%, $p < 0.0001$).

**Serious complications.** Major complications (i.e., death, myocardial infarction, sustained ventricular tachycardia or other conditions requiring inpatient observation) developed in 9 (0.3%) of 3,011 patients over 5 years. There were five cases of sustained ventricular tachycardia and one myocardial infarction, but neither ventricular fibrillation nor death occurred. Three additional patients required short-term inpatient observation for suspected myocardial infarction, supraventricular tachycardia and hypotension, respectively.

**Table 3.** Major Arrhythmias in 3,011 Dobutamine Echocardiograms Between 1991 and 1995

| | 1991–1993 | 1994 | 1995 | p Value |
|---|---|---|---|---|
| VT | 17 (2%) | 28 (3%) | 28 (2%) | 0.26 |
| Sustained VT | 3 (0.3%) | 1 (0.1%) | 1 (0.1%) | 0.30 |
| AF | 5 (0.6%) | 13 (1.4%) | 16 (1.3%) | 0.18 |

Data presented are number (%) of patients. AF = atrial fibrillation; VT = ventricular tachycardia.

The patient who had a myocardial infarction had an inferior myocardial infarction (treated with stenting of the right coronary artery) 1 month before dobutamine echocardiography. The test was performed because she continued to experience chest pain after intervention. Angina and inferior wall ischemia were induced by stress, which completely resolved by 6 min into recovery but recurred 15 min later. Coronary angiography revealed thrombotic occlusion of the stent in the right coronary artery. The patient admitted for severe ischemia had developed ST segment elevation, progressive chest discomfort and severe left ventricular dysfunction with peak infusion of 50 $\mu$g/kg per min and 1.0 mg atropine. This was thought to be consistent with severe three-vessel disease, but cardiac catheterization revealed completely normal coronary arteries without evidence of atherosclerosis. The event was thought to be due either to diffuse coronary artery spasm or to microvascular disease.

Of the patients with serious arrhythmias, one was observed in the hospital after sustained but asymptomatic supraventricular tachycardia (up to 175 beats/min) after peak infusion of 40 $\mu$g/kg per min of dobutamine and 0.8 mg of atropine. This arrhythmia persisted for 20 min in recovery before spontaneously converting back to sinus rhythm. Sustained ventricular tachycardia was controlled by intravenous lidocaine in one patient, and another required cardioversion; the other three recovered without medical intervention. No arrhythmic event was associated with signs of induced ischemia. Four patients had a history of myocardial infarction, one of repeated rapid supraventricular tachycardia.

**Minor complications.** *Hypotension.* The most frequent minor complication was hypotension, which occurred in 7% of patients (n = 198) and provoked test termination in 3.5% in the initial years and in 1.1% in the final year of the study. All patients completely recovered, usually after discontinuation of dobutamine; some patients required administration of fluids. These patients were older (69 ± 10 vs. 65 ± 12 years, $p < 0.0002$) and had a lower rest systolic blood pressure (139 ± 21 vs. 149 ± 26 mm Hg, $p < 0.0001$) and a slightly higher rest heart rate (78 ± 14 vs. 74 ± 14 beats/min, $p = 0.001$) than the rest of the group. The hypotensive response was less common in patients with beta-blocker therapy and was unrelated to ACE inhibitor or calcium antagonist therapy or the presence of hypertension, diabetes mellitus or preceding angina.

*Hypertension.* Hypertension (systolic blood pressure >220 mm Hg) occurred in 82 patients, 24 of whom had the test terminated for this reason. Hypertension settled spontaneously after conclusion of the protocol in most patients, but six required therapy with a beta-blocker or calcium antagonist, or both. A hypertensive blood pressure response correlated with a history of hypertension (54% vs. 40% in those without exaggerated response, $p < 0.02$) and beta-blocker therapy (45% vs. 19%, $p < 0.0001$). In the group with a hypertensive response, rest and peak heart rates were lower (68 ± 12 vs. 75 ± 14 beats/min and 119 ± 28 vs. 133 ± 17 beats/min,

respectively, both $p < 0.0001$), and rest systolic blood pressure was higher (171 ± 28 vs. 148 ± 26 mm Hg, $p < 0.0001$) than those without this complication.

*Arrhythmias.* Arrhythmias developed in 438 patients (15%), most frequently minor ventricular ectopic beats (n = 242). Mild atrial arrhythmias (including junctional rhythm and premature atrial contractions >10/min) and Wenckebach block occurred in 32 patients. The test was stopped because of these complications in only eight patients. Ventricular tachycardia occurred in 73 patients, leading to test termination in 18. The development of ventricular tachycardia did not correlate significantly with the total dose of dobutamine (20 vs. 26 mg in patients without ventricular tachycardia) or administration of atropine (19% vs. 31%) or with chest pain history (19% vs. 25%), beta-blocker therapy (15% vs. 20%), diuretic drug use (21% vs. 28%), diabetes mellitus (23% vs. 19%), hypertension (33% vs. 41%), age or body weight. However, whereas 45 patients with ventricular tachycardia also developed angina or ECG evidence of ischemia during dobutamine echocardiography, only 16 showed worsening wall motion scores (21% vs. 18% in patients without ventricular tachycardia, $p = 0.39$). Sustained supraventricular arrhythmias occurred in 85 patients (2.8%) (supraventricular tachycardia in 53, atrial fibrillation in 32) and led to early termination of the test in 18. Arrhythmias were no more frequent in 165 patients who were evaluated for at least moderate left ventricular dysfunction than in patients studied for other reasons (4.9% vs. 5.3%, $p = 0.94$), although the former less often achieved their target heart rate (65.5% vs. 73.2%, $p < 0.05$).

*Noncardiac side effects.* Significant noncardiac side effects occurred in 84 patients (2.8%), the most common of which were nausea (n = 54) and shortness of breath (n = 19). Three patients experienced severe headache (including one with typical migraine attack) and anxiety; other possible neurologic sequellae included myoclonic spasms, painful burning in the ears and transient double vision (each occurring in one patient). One patient developed a transient confusional state after being stressed with dobutamine without atropine.

## Discussion

The use of dobutamine echocardiography for the evaluation of known or suspected coronary artery disease in patients who cannot exercise adequately has expanded rapidly. The test, which is relatively inexpensive compared with competing technologies, is versatile and usually provides high quality images due to the absence of patient movement and limited respiratory interference. A number of studies have documented favorable sensitivity and specificity, especially with high dose protocols and supplemental administration of atropine (14,15,21). At the same time, with more aggressive protocols and inclusion of high risk patients with a potentially greater risk for complications, concerns have been raised about the safety of dobutamine echocardiography (18). Several studies have addressed this issue in the past, but these have involved less aggressive stress protocols and smaller numbers of patients from individual centers (16,17,22) or a multicentric approach, which may pose problems with respect to inhomogeneity of data collection and variations in patient selection.

**Present study.** The present single-center study of >3,000 consecutive examinations documents the safety and side effects of dobutamine echocardiography in relation to changes in the indications and protocol as the test has evolved over 5 years. The test was well tolerated in most patients who underwent dobutamine echocardiography at our institution from 1991 until 1995; major complications occurred in nine patients but no mortality. With the trend toward high dose protocols and administration of atropine in more than a third of the studies, the percentage of diagnostic tests (positive for ischemia or negative with a maximal heart rate response) increased from 59% to 80%. At the same time, fewer tests were stopped because of side effects (4% vs. 14%), reflecting increasing confidence in the safety of the dobutamine echocardiography protocol. Reduction of systolic blood pressure in the course of the test is now more readily accepted by the monitoring physician, and left ventricular outflow obstruction, which led to termination of the test in >5% of patients in 1993, was the end point in only 0.1% of studies in 1995. Similar trends can be observed with respect to the development of chest pain during dobutamine echocardiography; recently, we have terminated the test only for severe chest pain or if additional markers of ischemia were present. Continuing with the test despite the presence of angina permits definition of the the full extent of ischemia.

**Complications.** Neither death nor ventricular fibrillation occurred in our experience. The occurrence of myocardial infarction after dobutamine echocardiography in one patient supports the use of caution in severely symptomatic patients, even if the symptoms appear atypical. The patient with an apparently impending infarction after dobutamine echocardiography but without evidence of coronary disease at angiography may reflect a hyperadrenergic response or coronary spasm provoked by dobutamine (23). Serious complications from dobutamine echocardiography occurred in 1 of 335 tests, in agreement with previous, smaller studies (16,17,22), and somewhat less than the 1 in 210 incidence reported by Picano et al. (18). The main source of discrepancy was the absence of atropine induced psychosis during dobutamine echocardiography in our experience (indeed, the only patient who experienced an altered mental status with confusion and disorientation had not received any atropine). The frequency of serious events in all reported dobutamine studies is comparable to that reported for exercise testing in patients with coronary artery disease (24).

As reported by other investigators, the most commonly encountered adverse effects were arrhythmias and hypotension. The majority of arrhythmias were ventricular ectopic activity; more serious rhythm disorders (supraventricular tachycardia, ventricular tachycardia, atrial fibrillation) occurred in 107 patients (3.6%), similar to the experience of Mertes et al. (16) (4.3%) and Poldermans et al. (22) (3.6%). Atrial fibrillation and supraventricular tachycardia were well

tolerated by the patients and responded promptly to termination of the test; only six patients required medical intervention. Of five patients with ventricular tachycardia, hemodynamic variables remained stable in four, and only one required an electric countershock because of hemodynamic compromise. No clinical predictors of ventricular tachycardia could be identified, and its occurrence was not correlated with higher doses of dobutamine or administration of atropine, similar to the experience of McNeill et al. (14) and Mertes et al. (16). Patients with left ventricular dysfunction and those with a pacemaker had no higher risk of developing ventricular tachycardia than patients tested for other reasons.

Reduction of systolic blood pressure, which was the second most common side effect, was also well tolerated and readily reversed after test termination and intravenous fluids, if required. In the course of the study period, this side effect was less commonly a reason for stopping the test. Contrary to previous reports by Tanimoto et al. (25), we did not find a positive correlation between therapy with ACE inhibitors and a decrease in systolic blood pressure, or a correlation with elevated baseline systolic blood pressure, as described by Lieberman et al. (26). Administration of atropine during dobutamine echocardiography was inversely related to a decrease in systolic blood pressure, most likely by its vagal suppressant effect, supported by the finding that no patient with severe vagal reaction had received atropine during dobutamine echocardiography.

**Adequacy of stress.** The use of atropine has been shown (14,15) to increase the sensitivity of dobutamine echocardiography, especially in patients receiving treatment with beta-blockers. However, administration of atropine in the late stages of dobutamine echocardiography considerably prolongs the duration of the test, leading to infusion of a higher total dose of dobutamine. The use of greater doses of dobutamine, with and without atropine, has led to a higher percentage of diagnostic tests without increasing the risk of severe side effects.

**Conclusions.** The results of this single-center study of 3,011 consecutive studies confirm that dobutamine echocardiography is a safe test for the purposes of diagnosis and risk stratification in patients with known or suspected coronary artery disease. This has remained true despite the trend toward more aggressive protocols and inclusion of high risk patients. Further studies are necessary to investigate ways of optimizing the dobutamine echocardiographic protocol according to the needs of selected patient groups, such as those with diabetes mellitus or taking beta-blocker therapy.

We acknowledge the tireless work of the sonographers, fellows and staff of the Echocardiography Laboratory of the Cleveland Clinic Foundation.

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