

## **Comparison of Exercise Stress Testing with Dobutamine Stress Echocardiography and Radionuclide Ventriculography for Diagnosis of Coronary Artery Disease**

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### **SUMMARY**

Dobutamine stress echocardiography, Tc-99m radionuclide ventriculography (RNVG), and exercise stress testing were performed prospectively in 63 patients with suspected coronary artery disease to compare the values of exercise testing, dobutamine stress echocardiography and RNVG in the non-invasive diagnosis of coronary artery disease. The sensitivities of dobutamine stress echocardiography and RNVG were found to be higher than that of exercise testing (93–62%,  $p < 0.001$ ; 83–62%,  $p < 0.05$ ). The sensitivities of dobutamine stress echocardiography and RNVG were similar ( $p > 0.05$ ). There were no differences between the sensitivities of the three techniques in multiple vessel disease ( $p > 0.05$ ). The specificities of dobutamine stress echocardiography and RNVG were higher than that of exercise testing (for both of the tests 86–62%,  $p < 0.05$ ). The diagnostic accuracy of dobutamine stress echocardiography and RNVG were similar ( $p > 0.05$ ). The results of dobutamine stress echocardiography RNVG were concordant with each other in 46 patients (76%, kappa = 65%) in sectional analysis. Dobutamine stress echocardiography and RNVG tests were comparable with each other in 85% of the 189 segments (kappa = 64%). The expected 5% decrease at peak doses of dobutamine was not detected in stress echocardiography in 25 patients and in RNVG in 26 of the patients.

Dobutamine stress echocardiography and RNVG are superior to exercise testing in the diagnosis of single vessel disease and there is no significant difference between the two techniques. When the ejection fraction is considered in dobutamine stress echocardiography and RNVG, it does not make an addi-

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**C**ORONARY artery disease is an important problem in developed societies with respect to its frequency and fatal outcome.<sup>1)</sup> Therefore, the diagnosis and treatment of coronary artery disease is very important. Coronary artery disease can be diagnosed by the detection of ischemia induced by pharmacological agents like dobutamine, dipyridamole<sup>2-5)</sup> and stress modalities like exercise<sup>6-8)</sup> and atrial pacing.<sup>9)</sup> The ischemia can be detected by electrocardiography (ECG),<sup>10)</sup> echocardiography (ECHO),<sup>11-13)</sup> and radionuclide methods.<sup>14-16)</sup> Exercise ECG is widely used in the diagnosis of coronary artery disease. Its diagnostic value is limited to the diagnosis of single vessel disease. Nuclear ventriculography studies that obtain quantitative data can be used in the diagnosis of coronary artery disease. It has the disadvantage of being expensive and not practical. On the other hand, stress echocardiography is recently being used widely in the diagnosis of coronary artery disease. It is cheaper and more practical than nuclear ventriculography. The use of pharmacological stress agents and more qualified imaging techniques has increased the popularity of echocardiography in patients who are unable to perform exercise. Consequently, high diagnostic accuracy rates are achieved with the use of stress echocardiography. Exercise RNVG has been proven to be a sensitive method in the diagnosis of coronary artery disease.<sup>17,18)</sup> Although not widely used, the detection of pharmacologically induced ischemia by radionuclide ventriculography is another choice.<sup>19-21)</sup> Different sensitivity and specificity values have been reported. As far as we know, there are no studies comparing the detection of pharmacologically induced ischemia by ECHO and RNVG and the detection of exercise-induced ischemia by ECG.

In this study, our aim was to compare the diagnostic values of exercise ECG, dobutamine stress ECHO and dobutamine stress RNVG in coronary artery disease patients and to assess the diagnostic concordance between the dobutamine stress ECHO and dobutamine stress RNVG when the wall motion pathologies and the ejection fractions are studied separately.

## METHODS

**Study patients:** Sixty three patients (11 females, 52 males; mean age =  $51.49 \pm 10.49$ ; 29-70) with chest pain complaints admitted to the hospital for coronary angiography (CAG) underwent treadmill ECG, dobutamine stress ECHO, dobutamine stress RNVG and CAG within a week. All of them com-

plained of chest pain on effort. Twenty patients had had a previous myocardial infarction. Patients with unstable angina pectoris, myocardial infarction history within the past 2 months, cardiomyopathy, congestive heart failure, serious cardiac valvular disease, intractable hypertension, major ventricular arrhythmia or permanent pacemakers were not included in the study. Patients with a poor basal echocardiography window and those unable to perform an exercise test due to a poor medical condition were also excluded. In the case of patients under drug therapy, beta blockers were stopped 48 hours and calcium channel blockers and nitrates 24 hours before the study. The Hospital Ethics Committee approved the study and informed consent was obtained from each patient.

**Exercise test:** Exercise testing was performed using the Bruce protocol with continuous ECG monitoring. Blood pressure measurements and 12 lead ECG recordings were taken at the end of each stage and at peak exercise. The test was stopped when 2 mm or more ST segment depression or elevation, severe hypertension, a 20 mmHg or more decrease in systolic blood pressure, important arrhythmias or limiting symptoms were observed or when the target heart rate was reached. A test result was considered positive when there was  $\geq 1$  mm horizontal or downsloping ST-segment depression 80 ms after the J point in any lead except AVR, or a  $\geq 1$  mm ST-segment elevation in leads with no pathologic Q waves.

**Dobutamine stress echocardiography:** Dobutamine was administered intravenously by an infusion pump. Beginning with 5  $\mu\text{g}/\text{kg}/\text{min}$ , the dobutamine dosage was increased by 5  $\mu\text{g}/\text{kg}/\text{min}$  every 3 minutes up to a maximum of 40  $\mu\text{g}/\text{kg}/\text{min}$ . Dobutamine was stopped and intravenous metoprolol was used to prevent the ischemia induced by dobutamine. Patients who could not reach 85% of the maximum exercise speed determined by age, were given 1 mg or more atropine during dobutamine infusion.

Two dimensional echocardiography was performed using a Toshiba SSA 270-A ultrasound system (Tokyo, Japan) with a 3.75 MHz transducer using parasternal long-and short axis views acquired in the 30° left lateral decubitus position. Images were obtained in the 4 views during each stage (before dobutamine infusion "base", when 10  $\mu\text{g}/\text{kg}/\text{min}$  of dobutamine infusion was completed "low dose", when reached to the end point "peak dose" and 12 minutes after stopping dobutamine infusion "recovery"). Parasternal short-long axis, apical two-four space images were taken at the 30° left lateral decubitus position. These images were digitized and with the aid of a Freeland computer system recorded on an optic disk. This system digitizes and records 8 serial echocardiographic frames with 50 ms intervals during the systole of the single cardiac cycle determined by the electrocardiograms. Images can be shown by cine-loop format and can be estimated in a quadrscreen format. Ejection frac-

tions were calculated from the basal and peak dose images.

During the dobutamine infusion 12 lead ECG was monitored and recorded with one minute intervals and blood pressures measured by the cuff method and recorded with 3 minute intervals. The termination criteria of the test were detection of a new or progressively worsening wall motion abnormality, systolic blood pressure over 220 mmHg or diastolic blood pressure over 120 mmHg, more than a 20 mmHg decrease in systolic blood pressure, major ventricular arrhythmia, attaining the targeted heart rate (85% of the maximal heart rate determined according to age), 2 mm or more ST segment depression, or symptoms that were unbearable for the patient.

**Echocardiographic analysis:** The echocardiographic images were assessed by two experienced cardiologists who did not know the clinical examination or coronary angiogram results of the patients. When a disagreement occurred between the two, another cardiologist who did not know the previous assessments made an assessment and the parties came to an agreement. For this semiquantitative assessment, the left ventricle was divided into 16 segments determined by the American Echocardiography Association and scored according to the scale number 4:1 = normal, 2 = hypokinetic, 3 = akinetic, 4 = dyskinetic. Sixteen segments were combined and three major segments were formed (anterior, inferior, posterolateral). Both systolic wall thickening and wall motion towards the inside were assessed visually. A test was accepted as positive when there was a new or worsened wall motion abnormality revealed by an increase in the score of one or more.

**Dobutamine stress radionuclide ventriculography:** One mg stannous fluoride was given intravenously using a red cell kit (Amersham, UK). Twenty minutes later 20mCi Tc-99m pertechnetate was injected intravenously and thus the erythrocytes of the patients were tagged *in vivo*. Fifteen minutes later, imaging was conducted using a GE Starcam 3200 XR/T gamma camera, general purpose parallel perforated collimator and SAGE (Semi-Automatic Gated Evaluation of Blood pool images) protocol with the patient in the supine position. Patients were positioned such that the left ventricle was placed at the center of each image. Resting images were taken before dobutamine infusion; first under basal conditions at the anterior, lateral left anterior oblique (45°) position where the septum is best visualized and then finally at the left lateral position. For each image 4,800,000 counts were collected. According to the software used, one cardiac cycle (R-R distance) was divided into 24 frames and for arrhythmia rejection, with the use of a 20% window, data were collected in the frame mode.

After the resting images were taken, dobutamine was given intravenously via an infusion pump beginning at a dose of 5 µg/kg/min with 5 µg/kg/min increments every 3 minutes up to a maximum of 40 µg/kg/min. In order to

prevent ischemia caused by dobutamine, the agent was stopped and metoprolol was given intravenously. In patients who were unable to reach 85% of the maximal exercise rate determined by age, over 1 mg atropine was given intravenously during dobutamine infusion.

Images were collected upon completion of the low dose (10  $\mu\text{g}/\text{kg}/\text{min}$ ), when the target rate was reached (peak dose) and 12 minutes after the end of dobutamine infusion (recovery). RNVG uses an operator-assisted method to identify the borders of the left ventricle and to calculate a background-subtracted ejection fraction at basal and peak doses from the following formula:

$$\frac{\text{End Diastolic Counts}-\text{End Systolic Counts}}{\text{End Diastolic Counts}}$$

During the process of dobutamine infusion, the patients were monitored by ECG. Twelve lead ECG was recorded every minute and blood pressure was measured and recorded every 3 minutes. The termination criteria of the test were detection of a new or progressively worsening wall motion anomaly, systolic blood pressure over 220 mmHg or diastolic blood pressure over 120 mmHg, a more than 20 mmHg decrease in systolic blood pressure, major ventricular arrhythmia, attainment of the targeted heart rate (85% of the maximal heart rate determined according to age), 2 mm or more ST segment depression, or symptoms that were unbearable for the patient.

**RNVG analysis:** The left ventricle was divided into three major segments (anterior, inferior, posterolateral). The wall motions were interpreted independently by two experienced observers who did not know the clinical examination or catheterization results of the patients. The wall motions were scored as 1 = normal, 2 = hypokinetic, 3 = akinetic, 4 = dyskinetic. The test was accepted as positive when there was an increase in the stress score with respect to the resting score, namely when an aggravation of the existing wall motion anomaly or development of new wall motion anomalies were detected.

**Coronary angiography:** After the tests were completed all patients underwent coronary angiography and left ventriculography. Angiograms were assessed by two observers who did not know the clinical data of the patients. If the diameter of the vessel was reduced by 50%, it was considered to be a coronary stenosis.

**Statistical analysis:** All data are expressed as mean  $\pm$  SD. The sensitivities, specificities and diagnostic accuracy of the tests were calculated using standard formulas. The statistical significance was determined by comparing two proportions from independent groups using a hypothesis test on a microsta computer programme. A  $p$  value  $< 0.05$  was considered to be statistically significant. The concordance between the dobutamine stress echo and RNVG was accepted as the percentage of the diagnostic concordance and assessed by calculation of the

kappa value. The concordance was accepted as good when kappa was between 0.75–1, medium when the kappa was between 0.40–0.75, and bad when kappa was between 0.40–0.75.

## RESULTS

Dobutamine and exercise tests were completed in all patients without any serious complications (Table I). Termination points were reached in all patients. We applied atropine and reached the targeted heart rate in 15% of the patients

**Table I.** Adverse Effects during Dobutamine Stress Echocardiography and Radionuclide Ventriculography, and Exercise Electrocardiography (ECG)

	Dobutamine	Exercise
Symptomatic hypotension	0	1 (1.6%)
Systemic hypertension	0	5 (7.9%)
Palpitation	18 (27%)	2 (3.1%)
Headache	8 (12.7%)	0
Tremor	3 (0.47%)	0
Nausea	7 (11%)	0
Arrhythmia		
VPC	17 (27%)	5 (8%)
APC	12 (19%)	5 (8%)

VPC = ventricular premature complex; APC = atrial premature complex.

**Table II.** Changes in Heart Rate, Blood Pressure and Double Product during Exercise Stress Tests

	Heart rate		Systolic blood pressure		Double product	
	(beats.min <sup>-1</sup> )		(mmHg)		mmHg × (beats.min <sup>-1</sup> ) × 10 <sup>12</sup>	
	basal	peak	basal	peak	basal	peak
Dob. ECHO	73 ± 11	137 ± 15*	137 ± 23	160 ± 25*	100 ± 22	219 ± 42*
Dob. RNVG	74 ± 13	139 ± 16*	138 ± 21	158 ± 24*	102 ± 25	220 ± 41*
Exercise	76 ± 12	163 ± 20**	139 ± 19	181 ± 32**	105 ± 21	295 ± 64**

\**p* < 0.05 vs basal values; \*\**p* < 0.05 vs peak values of dobutamine test. Dob. ECHO = dobutamine echocardiography; Dob. RNVG = dobutamine radionuclide ventriculography.

**Table III.** Comparative Sensitivity, Specificity and Diagnostic Accuracy of Exercise Electrocardiography (ECG), Dobutamine Stress Radionuclide Ventriculography (RNVG) and Echocardiography (ECHO)

	Sensitivity (%)	Specificity (%)	Diagnostic accuracy (%)
Exercise ECG	26/42 (62)	13/21 (62)	39/63 (62)
Dobutamine RNVG	35/42 (83)*	18/21 (86) <sup>‡</sup>	53/63 (84) <sup>°</sup>
Dobutamine Echo	39/42 (93) <sup>ω</sup>	18/21 (86) <sup>‡</sup>	57/63 (90) <sup>δ</sup>

\**p* < 0.05 vs exercise ECG; <sup>ω</sup>*p* < 0.001 vs exercise ECG; <sup>‡</sup>*p* < 0.05 vs exercise ECG; <sup>°</sup>*p* < 0.05 vs exercise ECG; <sup>δ</sup>*p* < 0.001 vs exercise ECG.

who could not reach the maximum heart rate in the dobutamine stress test. Changes in heart rate, systolic blood pressure and double product during the dobutamine and exercise stress tests are shown in Table II. Double product at the ischaemic threshold was significantly higher during the exercise than the dobutamine test.

Coronary angiography revealed coronary artery disease in 42 patients. There was no significant coronary artery disease in the remaining 21. The exercise stress test with its 62% sensitivity and 62% specificity, reached a diagnostic accuracy of 62% (Table III). When wall motions were taken into consideration, the sensitivity, specificity and diagnostic accuracy of the dobutamine stress test in coronary artery disease cases were 93%, 86% and 90%, respectively. On the other hand, these values were 83%, 86% and 84%, respectively, for dobutamine stress RNVG. The sensitivity and specificity of dobutamine stress echocardiography and RNVG in detecting the coronary artery disease were significantly higher than that of the exercise test (sensitivity was 93%, 62%,  $p < 0.001$  and specificity was 86%, 62%,  $p < 0.05$ ; for both tests, respectively). Dobutamine stress echocardiography reached the highest diagnostic accuracy, however, the difference between it and dobutamine stress RNVG was not statistically significant ( $p > 0.05$ ). The diagnostic accuracy of both dobutamine stress echocardiography and dobutamine stress RNVG was significantly higher than that of exercise stress test (respectively 90%, 62%,  $p < 0.001$ ; 84%, 62%,  $p < 0.05$ ). When the changes in ejection fraction values that caused the test to be assessed as positive were taken into consideration, of the 42 coronary artery patients, a 5% ejection fraction according to the resting value was detected in 17 patients with dobutamine stress echocardiography and in 16 patients with dobutamine stress RNVG. The test was accepted as positive in patients whose basal ejection fractions were below 50% and their ejection fractions at peak dose were unable to increase by 5% with stress. When wall motion abnormality and ejection fraction criteria were considered together there was no increase in total sensitivity and specificity for either method.

**Angiocardiographic wall motion parallelism:** The results of the tests in single, double and triple vessel patients are presented in Table IV. The sensitivities of dobutamine echocardiography and RNVG in single vessel patients were significantly higher than that of exercise ECG (93%, 33%,  $p < 0.001$  and 87%, 33%,  $p < 0.05$  for both tests, respectively). All three methods exhibited similar sensitivities in diagnosing double and triple vessel disease (for two vessels 88%, 76%, 70%,  $p > 0.05$ , respectively, and for three vessels 100%, 90%, 90%,  $p > 0.05$ , respectively). In patients whose results were positive in dobutamine stress echocardiography and RNVG, the location of the wall motion abnormality induced by stress was in concordance with the distribution of stenotic coronary

**Table IV.** Sensitivity of Exercise Electrocardiography (ECG), Dobutamine Stress Radionuclide Ventriculography (RNVG) and Echocardiography (ECHO) for Detection of One, Two and Three-vessel Coronary Artery Disease

	Sensitivity (%)		
	1 Vessel	2 Vessel	3 Vessel
Exercise ECG	5/15 (33)	12/17 (70)	9/10 (90)
Dobutamine RNVG	13/15 (87)*	13/17 (76)	9/10 (90)
Dobutamine EKO	14/15 (93) <sup>o</sup>	15/17 (88)	10/10 (100)

\*  $p < 0.05$  vs exercise ECG; <sup>o</sup> $p < 0.001$  vs exercise ECG.

## E C H O

		Normal	Ischemia	Infarction +Ischemia
R N V G	Normal	18	5	2
	Ischemia	2	11	4
	Infarction +Ischemia	1	3	17

**Figure 1.** Results of dobutamine stress ECHO and RNVG. Squares 18, 11 and 17 show the results for patients who were concordant in both of the tests. Ischemia = New wall motion abnormality at peak doses of dobutamine. Infarction + Ischemia = New wall motion abnormality at peak doses of dobutamine together with wall motion abnormality at basal doses. ECHO = Echocardiography; RNVG = Radionuclide ventriculography.

arteries.

**Concordance with baseline wall motion:** Baseline wall motions were normal in all segments in 43 patients (68%). In the remaining 20 patients (32%) coronary artery disease and segmental wall motion abnormality were present. Among the 43 patients with normal baseline wall motion, 21 (49%) did not have significant coronary artery disease. The sensitivity of dobutamine stress echocardiography was 86% in patients without baseline wall motion abnormality and 100% in patients with baseline wall motion abnormality. On the other hand, the sensitivity of dobutamine stress RNVG was 73% in patients without baseline wall motion abnormality and 100% in patients with baseline wall motion abnormality.

**Concordance between stress echocardiography and RNVG:** The results of dobutamine stress echocardiography and dobutamine RNVG in 63 patients are shown in Figure 1. Echocardiography showed wall motion abnormality concor-



dant with ischemia in 42 patients whether with or without baseline wall motion abnormality. Test results were negative in 21 patients. Dobutamine RNVG showed wall motion abnormality concordant with ischemia in 38 patients whether with or without baseline wall motion abnormality. There were no wall motion abnormalities in 25 patients. The two methods were concordant with each other in 46 patients (76%, kappa = 65%). The coronary angiograms were normal in 17 of the 18 patients in whom both tests were negative. Significant coronary artery lesion was demonstrated in 1 patient, significant coronary artery disease was detected in 10 of the 11 patients in whom both tests showed new wall motion abnormalities, and baseline wall motion abnormality concordant with inferior MI was detected angiographically in one of them. Coronary angiograms were normal in 1 of the 11 patients. Significant coronary artery lesion was detected in 17 patients where both tests showed baseline and new wall motion abnormality, however, baseline new wall abnormality was not detected in 2.

### E C H O

		+		-		
R N V G	+	9	2	17	1	Anterior-septal
		4	28	0	2	
	-	3	2	3	3	Posterior-lateral
		2	36	1	13	
	+	2	4	5	4	Inferior
		4	33	1	10	
		MI -		MI +		
		Concordance=88%		Concordance=83%		
		Kappa=60%		Kappa=66%		

**Figure 2.** Regional concordance between dobutamine stress ECHO and RNVG in total of 189 segments for determining the ischemia. The tables on the left show the data for non-MI patients; those on the right show the MI patients. ECHO = Echocardiography; RNVG = Radionuclide ventriculography.

When the coronary angiograms of the 5 cases whose RNVG were normal and echocardiographies were positive for new wall motion abnormality were examined, coronary artery disease was detected in 4 patients while no significant lesion was detected in 1 patient. There was no significant coronary artery disease in one of the two patients in whom RNVG showed wall motion abnormality and echocardiography was normal. Coronary artery disease was detected in 6 patients who were documented to have baseline and new wall motion abnormality by echocardiography, and normal (2 patients) or new wall motion abnormality (4 patients) by RNVG. While baseline wall motion abnormality was detected by angiography in 5 of them, no wall motion abnormality was present in 1 patient in whom new wall motion abnormality was detected by RNVG. Coronary artery disease was detected in 2 of 3 patients who were found to have baseline wall motion abnormality and new wall motion abnormality by RNVG and new wall motion abnormality by echocardiography. Baseline wall motion abnormality was demonstrated by angiography in 3 of them. Coronary artery disease was detected in one patient in whom no wall motion abnormality was present in echocardiography but baseline and new wall motion abnormality in RNVG. Baseline wall motion abnormality was also detected in this patient.

**Complete regional concordance:** Complete regional concordance was 85% ( $\kappa = 64\%$ ). When compared with the MI patients, the concordance was higher in the ones without MI (respectively 83%,  $\kappa = 66\%$ ; 88%,  $\kappa = 60\%$ , Figure 2). Different results were obtained in 28 segments; 18 of which were in 43 non-MI patients and 10 of which were in 20 MI patients.

## DISCUSSION

Coronary artery disease is an important clinical problem because of its high mortality and morbidity. Early and true diagnosis of this disease by non-invasive screening tests constitutes an important part of the cardiology practice. Although exercise ECG is the first step in the diagnosis of coronary artery disease because of its easy applicability, it has a low sensitivity in single vessel disease patients especially. Echocardiographic diagnosis of myocardial ischemia was first shown by Wann *et al.* in 1979.<sup>22)</sup> Echocardiographic techniques combined with different stress modalities are used with high sensitivity in coronary artery disease.<sup>2-5,11-23)</sup> As the mechanism of the dobutamine effect is similar to exercise, the combination of dobutamine stress with echocardiography is a preferred method. Radio-nuclide ventriculography is known to be more sensitive in the diagnosis of myocardial ischemia when compared with dobutamine echocardiography, but its disadvantages are its high-cost to the patient, exposure of the patient to radiation, and unavailability of the equipment.

The ischemia induced by stress can be detected either by the development of wall motion abnormalities or by the changes in ejection fraction. The presence of baseline wall motion abnormality, development of new wall motion abnormalities with physical exercise and an increase in ejection fraction during peak exercise below 5% with respect to resting value renders the test positive. It is reported that the diagnostic value of exercise RNVG increases when both wall motion anomaly and ejection fraction are assessed together.<sup>24)</sup> The expected 5% decrease in ejection fraction was not detected in dobutamine stress RNVG studies which were only done for the diagnosis of coronary artery disease.<sup>21,25)</sup> We did not encounter a study involving assessments about the changes in dobutamine stress echocardiography and ejection fraction in the literature. In our study we could not detect the 5% decrease occurring at peak exercise in 26 of the 42 coronary artery disease patients by RNVG, nor in 25 of the 42 coronary artery disease patients by echocardiography. It is thought that in these cases where a 5% or more decrease in ejection fraction was not observed, dobutamine, by inducing maximal contraction in nonischemic myocardium, lead to the compensation of the expected decrease in ejection fraction (Figures 3 and 4).

To our knowledge there has not been any published data comparing the echocardiographic and RNVG diagnosis of ischemia induced by dobutamine. In this study, we tried to detect and compare the echocardiographic and RNVG

		CHD	
		-	+
5% Increase	-	3	17
	+	18	25

**Figure 3.** Five percent increase detected and not detected in ejection fraction by dobutamine stress ECHO in patients who have and do not have CHD (Coronary Heart Disease).

		CHD	
		-	+
5% Increase	-	4	16
	+	17	26

**Figure 4.** Five percent increase detected and not detected in ejection fraction by dobutamine stress RNVG in patients who have and do not have CHD.

diagnosis of the ischemia induced by the same level of dobutamine stress. In these cases exercise ECG and coronary angiography were accepted as standard references. When the baseline wall motion abnormalities or the ones developed after the infusion of dobutamine are taken into consideration, although statistically insignificant ( $p > 0.05$ ), the sensitivity of dobutamine stress echocardiography was found to be higher than that of dobutamine stress RNVG. It is thought that the high sensitivity of dobutamine stress echocardiography was due to the detectability of the myocardial wall thickness in addition to the detection of the wall motion abnormalities by echocardiography. The detection of the dobutamine induced wall motion abnormalities either by echocardiography or by RNVG were in good concordance.

Although the diagnostic value of dobutamine stress echocardiography and RNVG in single vessel disease are high, both of the tests have some disadvantages compared to exercise testing. In our study we needed  $51 \pm 9.2$  minutes for dobutamine stress echocardiography and  $60 \pm 8.7$  minutes for dobutamine stress RNVG to perform and interpret. On the other hand, it took  $20 \pm 4.5$  minutes for the exercise test. When evaluated with respect to cost, echocardiography and RNVG are more expensive techniques. The detection of ejection fractions with dobutamine stress echocardiography and RNVG did not increase the diagnostic values of these tests. The instruments necessary for the tests, especially for RNVG, are not available in many centers. Because of these disadvantages, dobutamine echocardiography and RNVG are not screening tests but rather are considered to be complementary tests.

**Conclusion:** Dobutamine induced ischemia is detected by echocardiography and RNVG at similar rates. When compared with the exercise stress test, resting and peak dose ejection fraction changes do not contribute much to the diagnosis of coronary artery disease. In patients unable to exercise or in cases where the exercise test remains inadequate in the diagnosis of coronary artery disease, dobutamine stress echocardiography and RNVG with their high sensitivity and specificity can be used as complementary tests.

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