REVIEW ARTICLE

The Role of Stress Electrocardiography in Modern Cardiology

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Abstract

Aim: To point out the importance of stress electrocardiography and to present the indications, contraindications, as well as reasons for test termination with reference to the interpretation of the findings.

Background: Despite the development of modern cardiology and the availability of methods for the visualization of coronary artery disease (CAD), stress electrocardiography still has a role in clinical practice.

Review results: It is a safe, affordable, and cheap test for the evaluation of CAD, with clear indications, contraindications, and a clearly defined population for which it is intended.

Conclusion: It is imperative to correlate findings of stress electrocardiography with clinical symptoms, comorbidities, positive family history, and life habits, as well as pharmacological therapy of the patient.

Clinical significance: Stress electrocardiography should be a part of the daily work of cardiologists.

Keywords: Electrocardiography, Heart, Ischemia, Prevention.

Sažetak

Cilj: Ukazati na važnost stres elektrokardiografije te prikazati indikacije, kontraindikacije, kao i razloge prekida pretrage s osvrtom na interpretaciju nalaza.

Pozadina: Usprkos razvoju moderne kardiologije i dostupnosti metoda za vizualizaciju koronarne arterijske bolesti, stres elektrokardiografija još uvijek ima ulogu u kliničkoj praksi.

Rezultati pregleda: To je siguran, pristupačan i jeftin test za procjenu koronarne arterijske bolesti, s jasnim indikacijama i kontraindikacijama i jasno definiranom populacijom kojoj je namijenjen.

Zaključak: Neophodno je povezati nalaz stres elektrokardiografije s kliničkim simptomima, komorbiditetima, pozitivnom obiteljskom anamnezom i životnim navikama, kao i farmakološkom terapijom bolesnika.

Klinički značaj: Stres elektrokardiografija bi trebala biti dio svakodnevnog rada kardiologa.

Science, Art and Religion (2022): 10.5005/jp-journals-11005-0019

Background

Stress electrocardiography (ergometry) is a safe and affordable test for evaluating CAD.[1] The treadmill is the most commonly used device for stress electrocardiography, according to the already defined protocol.[1–3] The Bruce protocol is most commonly in use (others are protocols according to Balke, Astrand, and Naughton).[1,2] The advantage of the treadmill over other types of ergometers is that normal daily physical activities are simulated, which enables the actual presentation of oxygen consumption.[2]

The degree of load lasts for 3 minutes with a gradual increase in inclination and treadmill movement speed [initial treadmill inclination in the first stage of exercise is 10% at a speed of 1.7 m/hour or 2.7 km/hour (Table 1)]. Arterial pressure is measured every 2 minutes, and the electrocardiogram (ECG) is monitored by the physician (the ECG paper moves at a speed of 25 mm/second, with a

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deviation of 10 mm/1 mV). According to the Bruce protocol, the aim is to achieve submaximal or maximum load of the patient.[4–7] The unit of measurement that makes it easier to compare the load achieved during the test with the load in everyday life is one metabolic equivalent (MET) unit. One MET is the consumption of 3.5 mL of oxygen/kg/minute and is equal to resting metabolism.[5–7]

The recommendation is that the test should be performed until the submaximal heart rate is achieved (85% of the maximum heart rate for age and sex), or until the presentation of clinical symptoms.[6,7]

A bicycle ergometer is a stationary bicycle, and the load is created through the resistance and speed of the pedals (protocols according to James, McMaster, and Godfrey, Wingate anaerobic test, and force velocity test). There are also modifications of stress testing with step load tests (step ergometer), which include the Master step test, the Harvard step test, the Nagle progressive continuous step test, the Tennessee progressive continuous step test, and the progressive intermittent step test.

Arm stress electrocardiography is used in populations with physical disabilities of the lower extremities.

Review Results

Indications and Contraindications for Stress Electrocardiography

It is very important to optimally select patients for this test. Patients with moderate risk for CAD represent the best candidates, with the exception of females during their reproductive period when a high incidence of false positive results has been reported.[7–9] The sensitivity (true positive rate) of the test is 45–50%, and the specificity (true negative rate) is 85–90%, indicating that the use test for the exclusion of CAD is probably better than confirmation of the diagnosis of CAD.[8–16] The test is not recommended for use in patients with low (<15%) or high (>85%) pretest probability of CAD (Tables 2 and 3).[8,16] If the patient has a high probability of having CAD, stress electrocardiography should be combined with other methods of visualization of coronary arteries, or cardiac catheterization should be performed.[10] Indications for treadmill testing are shown in Table 4 and contraindications in Table 5.

Stress testing can be done in the first 7 days after an acute myocardial infarction but with a low-level of load.

Table 1: Bruce protocol[4,5]

Degree of load	*Load duration (minutes)*	*Speed (km/hour)*	*Grade (%)*	*The METs of task*
I	3	2.7	10	2–4
II	3	4.0	12	5–7
III	3	5.5	14	8–10
IV	3	6.7	16	11–12
V	3	8.0	18	13–15
VI	3	8.8	20	16–18
VII	3	9.6	22	19–21

How to cite this article: Iglica A, Begic E, Dzubur A, *et al.* The Role of Stress Electrocardiography in Modern Cardiology. Sci Arts Relig 2022;1(2–4):243–248.

Source of support: Nil

Conflict of interest: None

A full exercise test should be delayed for 4–6 weeks after myocardial infarction.[1]

Complications of stress electrocardiography are rare. Serious complications (myocardial infarction, sustained ventricular arrhythmia, and death) occur in one out of 10,000 patients.[10,11]

Methodology of Stress Electrocardiography

It is best to perform stress electrocardiography in the morning or before noon. The optimum room temperature

Table 2: Clinical pretest probabilities in patients with stable chest pain symptoms—male population[16]

Age	*Typical angina*	*Atypical angina*	*Nonanginal pain*
30–39	59%	29%	18%
40–49	69%	38%	25%
50–59	77%	49%	34%
60–69	84%	59%	44%
70–79	89%	69%	54%
>80	93%	78%	65%

Table 3: Clinical pretest probabilities in patients with stable chest pain symptoms—female population[16]

Age	*Typical angina*	*Atypical angina*	*Nonanginal pain*
30–39	28%	10%	5%
40–49	37%	14%	8%
50–59	47%	20%	12%
60–69	58%	28%	17%
70–79	68%	37%	24%
>80	76%	47%	32%

Table 4: Indications for stress electrocardiography[1]

Symptoms that may be associated with myocardial ischemia
Chest pain in patients for which acute coronary syndrome has not been verified
Recent acute coronary syndrome that is treated without coronary angiography or involves incomplete revascularization
Already existing CAD with worsening symptoms
Previous coronary revascularization (patients 5 years or longer after coronary artery bypass grafting or 2 years or less after percutaneous coronary intervention)
Valvular heart disease (for the purpose of evaluating the need for surgery)
Previous arrhythmia
Newly diagnosed heart failure or cardiomyopathy

should be between 18° and 22°, while air humidity should be >80%. The test room should be equipped with a defibrillator, bag valve (ambu) mask, tracheobronchial intubation kit and intravenous infusion set, and first aid and resuscitation medications.[15]

The electrodes have to be placed on the chest and connected to an ECG machine, which is usually connected to a computer that monitors the electrical activity of the heart. Before starting the test, the physician has to interpret the ECG at rest, record the heart rate, and measure arterial blood pressure (Fig. 1).

Table 5: Contraindications for stress electrocardiography[1]

Absolute
Acute myocardial infarction within 2–3 days
Unstable angina pectoris (refractory to therapy)
Cardiac arrhythmias, with clear symptoms or effects on the hemodynamic system
Symptomatic severe aortic stenosis
Symptomatic heart failure
Acute pulmonary thromboembolism
Severe pulmonary hypertension
Acute myocarditis or pericarditis, or endocarditis
Acute aortic dissection
Relative
Left main stenosis
High-grade atrioventricular block
Hypertrophic cardiomyopathy and other forms of outflow tract obstruction
Electrolyte imbalance
Severe hypertension (systolic blood pressure >200 mm Hg, diastolic blood pressure >110 mm Hg, or both)
Extreme obesity
Physical/mental impairment

The examiner is required to ask the patient about the possible use of pharmacological agents [β-blockers, calcium channel blockers, digoxin, and antiarrhythmic medications (it is recommended not to take them at least the day before the test)]. Older literature states that digoxin should be discontinued up to 3 weeks before the test in order to eliminate the effect of digitalis.[15] Nitroglycerin should not be taken 1 hour before the test. Patients should be instructed not to eat, drink, or smoke for at least 3 hours before the examination, as this can affect maximum exercise capacity. The night before the test, the patient should sleep well and be rested. Intense physical activity during the previous day due to muscle inflammation or residual hypertonia may result in decreased exercise tolerance. It is also useful to determine angina severity according to the Canadian Cardiovascular Society (Table 6).[16]

It is very important that the patient on the test is calm, as feelings of fear or anxiety can lead to emotionally conditioned tachycardia. Furthermore, drinking tea or coffee before the

Table 6: Classification of angina severity according to the Canadian Cardiovascular Society[16]

Class I	Daily activities do not create chest pain, angina occurs during prolonged physical activity.
Class II	Slight limitation of daily activities, Angina after walking over 200 m or stairs higher than the first floor.
Class III	Chest pain is present during daily physical activities, angina after walking up to 200 m or stairs to the first floor.
Class IV	Impossibility to perform even the smallest activities without chest pain, chest pain also occurs at rest.

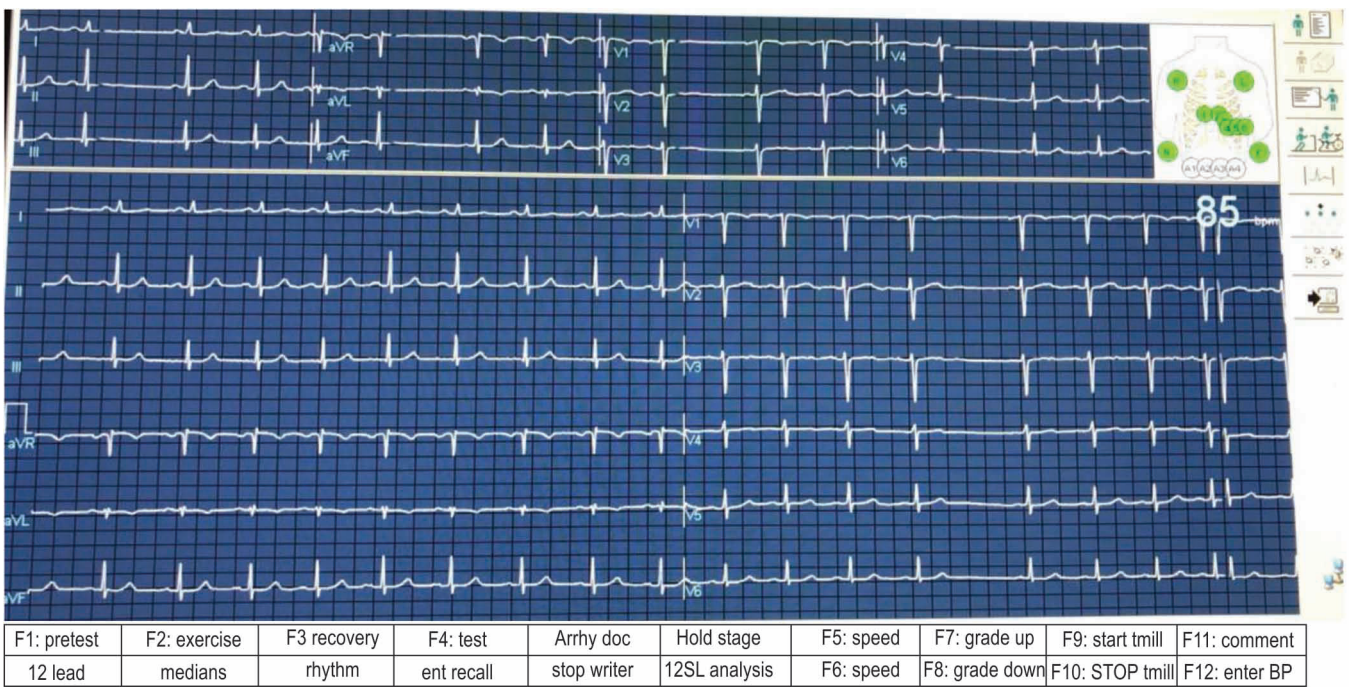

Fig. 1: ECG at rest, picture on the monitor

test can have a direct negative hyperexcitability effect on the heart. The patient should bring comfortable exercise clothing and walking shoes to the testing facility. Also, the examiner must present to patients any complications that may arise during testing. Auscultation of the heart before the test is recommended. It is necessary to calculate the maximum predicted heart rate (MPHR), taking into account the patient's height and weight. Angina or significant ST depression (>2 mm) before completing stage II according to Bruce protocol, and ST depressions that persist for >5 minutes into recovery, suggest severe ischemia and high-risk for coronary events.[15] Tests are considered positive for ischemia if there is a 2 mm or more rapidly upsloping ST depression (when the slope is >1 mV/second) and 1.5 mm or more slowly upsloping ST depression (when the slope is <1 mV/second), or a 1 mm or more horizontal or downsloping ST depression.[12–15] During the test, both the objective and the subjective status of the patient, are monitored.[15] After the load phase, the recovery phase requires ECG monitoring, and data on heart rate and blood pressure are recorded.

The formation of the right bundle branch block (RBBB) or left bundle branch block (LBBB) during exercise is not a specific sign, but if it is accompanied by chest pain, it indicates ischemia. The use of nitro preparation due to chest pain in the recovery phase may mask the signs of myocardial ischemia.[15] Subjective reasons for discontinuation of the stress test include a feeling of fatigue (general or local in the form of leg pain), shortness of breath (usually occurs in patients with chronic obstructive pulmonary disease and cardiovascular patients), dizziness and fainting, headache (most often in hypertensive reactions), palpitations, chest pain, and lack of motivation.[15]

Discussion

Indications for Discontinuation of the Test

The presence of LBBB, left ventricular hypertrophy, digoxin use, and RBBB marked ST abnormalities at baseline with ST depression >1 mm in at least two leads, paced ventricular rhythm and preexcitation syndrome (Wolff-Parkinson-White). They may interfere with the interpretation of the test. Indications for discontinuation of the test are shown in Table 7.

The test is considered inadequate if 85% of the MPHR is not reached. Initially, if there is LBBB, RBBB, paced rhythm, left anterior fascicular block (sensitivity of stress electrocardiography is below 39% in patients with left anterior fascicular block, exercise-induced can be a sign of severe myocardial ischemia, hypertrophy of left ventricle with repolarization changes, or digoxin therapy; therefore, the test is considered not to be adequate to evaluate ischemic heart disease).[15–20]

Also, the existence of mitral or aortic valve dysfunction or mitral valve prolapse, pulmonary hypertension, pericardial constriction, hypokalemia, glucose ingestion prior to the test, and treatment with endogenous estrogen (it has a digoxin-like effect) interfere with test interpretation.[15–18]

Stress Electrocardiography in the Pediatric Population

The first indication for pediatric stress electrocardiography is the evaluation of congenital heart defects (CHDs) (Table 8).

Patients with hypertrophic cardiomyopathy may be tested to assess the risk of sudden cardiac death.[21] A hypertensive or hypotensive response may be a sign of hemodynamic instability.[21]

After Kawasaki disease, especially if the patient had a coronary aneurysm, stress electrocardiography should be used during the examination.[21] Stress electrocardiography can be used for the detection of congenital long QT syndrome and Brugada syndrome.[21] It also presents a test to confirm catecholaminergic polymorphic ventricular tachycardia.[21] Exercise-provoked arrhythmias may develop in arrhythmogenic right ventricular dysplasia (typical is the occurrence of monomorphic ventricular tachycardia with an LBBB pattern).[21] Stress electrocardiography may distinguish resting bradycardia and chronotropic response from sinus node dysfunction.[21] Also, indications for the use

Table 7: Indications for discontinuation of the test[1,14,15]

Hypotension with systolic blood pressure drop >20 mm Hg (high-risk criteria) or systolic blood pressure drop >10 mm Hg.
Malignant disorders of rhythm, ventricular or supraventricular origin.
Severe hypertension, systolic blood pressure >250 mm Hg or diastolic blood pressure >120 mm Hg.
ST elevation (>1 mm in leads without Q waves).
Angina with ST segment changes.
ST depression >2 mm horizontal or down sloping.
Pallor or cyanosis as signs of hypoperfusion.
The maximum predicted frequency is reached.
>2 mm ST depression in multiple leads, ST elevation or change of ST segment or T wave in the recovery phase.

Table 8: Indications for pediatric stress electrocardiography[21–25]

Closed atrial or ventricular septal defect with persisting pulmonary hypertension.
Myocardial dysfunction, symptomatic tachyarrhythmias, or significant heart block.
Moderate aortic stenosis; untreated mild coarctation of the aorta or repaired aortic coarctation, even with good results.
Atrial or arterial switch operation for transposition of the great arteries.
Congenitally corrected transposition of the great arteries.
Repaired tetralogy of fallot and other repaired cyanotic CHD, including Fontan and total cavopulmonary connections.
Ebstein anomaly.
Repaired congenital coronary artery anomalies.

are detection of myocardial ischemia, assessment of ability to work, trying to find contraindications for sports activities, evaluation of drug treatment results and prognosis, chest pain, and assistance in evaluation of hypertension and transient loss of consciousness.[21,25]

Conclusion

Although the increasing availability of radionuclide myocardial perfusion imaging (single-photon emission computed tomography or positron emission tomography), multislice scanner coronary angiography, stress echocardiography, hybrid imaging, and invasive coronarography, stress electrocardiography still has its place in clinical practice. It is imperative to correlate findings of stress electrocardiography with clinical symptoms, comorbidities, positive family history, and life habits, as well as pharmacological therapy of the patient.

Clinical Significance

Stress electrocardiography should be part of the daily work of cardiologists.

Author's Contribution

Each author made substantial contributions to the conception or design of the work and to the acquisition, analysis, and interpretation of data for the work. Each author had a role in drafting the work and revising it critically for important intellectual content. Each author gave the final approval of the version to be published, and they agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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