ASSESSMENT OF EXERCISE TOLERANCE IN PATIENTS WITH ACUTE MYOCARDIAL INFARCTION AFTER ANGIOPLASTY IN A MULTIDISCIPLINARY HOSPITAL

Evgeny V. Rybin[1], Andrey S. Galenko[2], Subhayu Sikdar[2]
[1]St. Petersburg State Medical Institution "City Hospital of the Holy Martyr Elizabeth" (St. Petersburg State Medical Institution "Elizavetinskaya Hospital"), St. Petersburg, Russia
[2]St. Petersburg State Pediatric Medical University, St. Petersburg, Russia

Abstract
Currently, according to the St. Petersburg CardioRegistry since 2016, which includes the entire volume of medical care provided to all patients with acute coronary syndrome in all medical institutions of St. Petersburg, there is no data on the performance of exercise tests to assess exercise tolerance (ET) before the end of the inpatient treatment phase. Assessment of ET before discharge from the hospital or transfer to a rehabilitation department is important not only for evaluating the effectiveness of endovascular treatment but also for effective and safe cardiac rehabilitation of patients after acute myocardial infarction (AMI) at all stages. Predicting the construction of personalized cardiac rehabilitation programs based on different ET in patients with varying degrees of myocardial revascularization and left ventricular contractile function will be the basis for recommendations on early effective rehabilitation after revascularization surgery. These programs will undoubtedly determine the success of rehabilitation measures at subsequent stages for restoring the health and ability to work of patients, as well as reducing the risks of recurrent coronary events. The aim of the work is to evaluate the safety of using exercise tests in the early stages of AMI treatment and to determine the difference in ET in patients with varying degrees of myocardial revascularization and left ventricular contractile function for the subsequent construction of personalized cardiac rehabilitation programs. Materials and methods. We examined 173 patients urgently admitted to the regional vascular center with AMI (Q-AMI – 95 patients, non-Q-AMI – 78 patients) aged 38 to 79 years (average age 59±11 years). Patients underwent coronary angiography, emergency angioplasty and coronary artery stenting, and echocardiography to assess left ventricular ejection fraction (LVEF). Patients were divided into groups depending on the completeness of myocardial revascularization and LVEF. Upon discharge from the hospital, transfer to a rehabilitation department or a specialized sanatorium (average hospitalization duration was 11 days), stress tests were performed: a six-minute walk test (6MWT), and bicycle ergometry test (BET) on a vertical or horizontal bicycle ergometer (Schiller), which determined ET. The results of the work showed that with proper clinical selection of patients, taking into account the severity of cardiovascular diseases and concomitant somatic pathology, with an assessment of the risks of complications, performing stress tests by qualified medical staff of a multidisciplinary hospital before discharge is a safe method of functional diagnosis. Significant differences in ET in patients in different groups were identified, which allows for a personalized approach in the early inpatient stage of cardiac rehabilitation, including individual metered physical activity.

Conclusion: The completeness of myocardial revascularization and LVEF are among the significant factors affecting ET in patients with AMI after endovascular surgery and should be taken into account when designing personalized cardiac rehabilitation programs. A personalized approach based on clear clinical, laboratory, and instrumental data will improve the cardiac rehabilitation system for patients after AMI in general.

KEY WORDS: acute myocardial infarction, exercise tolerance, angioplasty, coronary artery stenting, six-minute walk test

ОЦЕНКА ПЕРЕНОСИМОСТИ ФИЗИЧЕСКОЙ НАГРУЗКИ У ПАЦИЕНТОВ С ОСТРЫМ ИНФАРКТОМ МИОКАРДА ПОСЛЕ АНГИОПЛАСТИКИ В МНОГОПРОФИЛЬНОЙ БОЛЬНИЦЕ

Евгений В. Рыбин[1], Андрей С. Галенко[2], Субхаю Сикдар[2]
[1]Санкт-Петербургское государственное медицинское учреждение «Городская больница Святой Мученицы Елизаветы», Санкт-Петербург, Россия
[2]Санкт-Петербургский государственный педиатрический медицинский университет, Санкт-Петербург, Россия

Аннотация
В настоящее время, согласно данным Санкт-Петербургского кардиореестра с 2016 года, охватывающего весь объем медицинской помощи, оказанной всем пациентам с острым коронарным синдромом во всех медицинских учреждениях Санкт-Петербурга, отсутствуют данные о проведении нагрузочных тестов для оценки переносимости физической нагрузки (НТ) до окончания стационарного лечения. Оценка физической нагрузки перед выпиской из стационара или переводом в реабилитационное отделение важна не только для оценки эффективности эндоваскулярного лечения, но и для эффективной и безопасной кардиореабилитации пациентов после острого инфаркта миокарда (ОИМ) на всех стадиях. Прогнозирование построения персонализированных программ кардиореабилитации на основе различной физической нагрузки у пациентов с разной степенью реваскуляризации миокарда и сократительной функцией левого желудочка станет основой для рекомендаций по ранней эффективной реабилитации после реваскуляризационной хирургии. Эти программы, несомненно, определят успех реабилитационных мероприятий на последующих этапах восстановления здоровья и трудоспособности пациентов, а также снижения риска повторных коронарных событий. Цель работы – оценить безопасность использования нагрузочных тестов на ранних стадиях лечения ОИМ и определить различия в физической нагрузке у пациентов с разной степенью реваскуляризации миокарда и сократительной функцией левого желудочка для последующего построения персонализированных программ кардиореабилитации. Материалы и методы. Мы обследовали 173 пациента, экстренно поступивших в региональный сосудистый центр с острым инфарктом миокарда (ОИМ) (Q-ОИМ – 95 пациентов, не-Q-ОИМ – 78 пациентов) в возрасте от 38 до 79 лет (средний возраст 59±11 лет). Пациентам проводили коронарную ангиографию, экстренную ангиопластику и стентирование коронарных артерий, а также эхокардиографию для оценки фракции выброса левого желудочка (ФВЛЖ). Пациенты были разделены на группы в зависимости от полноты реваскуляризации миокарда и ФВЛЖ. При выписке из больницы, переводе в реабилитационное отделение или специализированный санаторий (средняя продолжительность госпитализации составляла 11 дней), проводились стресс-тесты: шестиминутный тест ходьбы (6МТ) и велоэргометрический тест (ВЭТ) на вертикальном или горизонтальном велоэргометре (Шиллера), определявший ЭТ. Результаты работы показали, что при правильном клиническом отборе пациентов с учетом тяжести сердечно-сосудистых заболеваний и сопутствующей соматической патологии, с оценкой риска осложнений, проведение стресс-тестов квалифицированным

медицинским персоналом многопрофильной больницы перед выпиской является безопасным методом функциональной диагностики. Были выявлены значительные различия в физической нагрузке у пациентов разных групп, что позволяет применять персонализированный подход на раннем стационарном этапе кардиореабилитации, включая индивидуальную дозированную физическую активность.

Вывод: Полнота реваскуляризации миокарда и фракция выброса левого желудочка являются одними из значимых факторов, влияющих на физическую нагрузку у пациентов с острым инфарктом миокарда после эндоваскулярной хирургии, и должны учитываться при разработке персонализированных программ кардиореабилитации. Персонализированный подход, основанный на четких клинических, лабораторных и инструментальных данных, улучшит систему кардиореабилитации пациентов после острого инфаркта миокарда в целом.

КЛЮЧЕВЫЕ СЛОВА: острый инфаркт миокарда, переносимость физической нагрузки, ангиопластика, стентирование коронарных артерий, шестиминутный тест ходьбы

INTRODUCTION

According to WHO data, more than 7 million people annually suffer an acute myocardial infarction (AMI), which is associated with high mortality rates from complications of cardiovascular diseases, disability, loss of work capacity, and, consequently, significant socio-economic damage [1,2]. In the Russian Federation, thanks to the Federal Project "Fighting Cardiovascular Diseases," the effectiveness of medical care for patients with acute coronary syndrome is being improved. Measures for the prevention of cardiovascular diseases and cardiovascular complications in high-risk patients under dispensary dynamic observation are actively being implemented.Drug provision for patients who have suffered acute cardiovascular diseases at the outpatient stage has been organized, and the material and technical base of regional vascular centers and primary vascular departments has been updated. The latest endovascular surgery technologies are being actively introduced (assessment of the severity of atherosclerotic coronary artery lesions using intravascular ultrasound, assessment of fractional flow reserve, rotational atherectomy of calcified and occluded coronary arteries, implantation of drug-eluting stents), which ensures a more complete volume of myocardial revascularization while reducing the intensity of surgical aggression on the coronary arteries. The improvement of effective endovascular treatment for patients with AMI contributes to rapid stabilization of the condition, reduction of complications, and shorter stays in intensive care units. Early motor activation of patients has a beneficial effect on the physical and mental state of patients, shortens the hospitalization period, and reduces the risk of death. Early initiation of physical training increases exercise tolerance (ET), improves myocardial contractile properties, stimulates the development of collaterals, prevents hypostatic pneumonia, thromboembolic complications, prevents the decompensation of heart failure, reduces the frequency of post-infarction angina, has a beneficial effect on platelet aggregation, lipid profile indicators, electrolyte balance, psychological status, ultimately improving the quality of life and treatment prognosis for the patient [3].

Increasing physical activity after AMI is an effective approach to improving muscle metabolism, vasodilation, and increasing peak oxygen consumption by muscles, including the myocardium, which is accompanied by a positive effect on the cardiovascular system (adaptive, antiatherogenic, and antiarrhythmic) and on the main cardiovascular risk factors (dyslipidemia, obesity, arterial hypertension, diabetes mellitus, psychological distress) [4,5].

However, patients after myocardial infarction and revascularization surgery represent an extremely heterogeneous group in terms of the state of the cardiovascular system, the volume and type of revascularization, and concomitant somatic pathology, which requires a personalized approach to the design and prediction of cardiac rehabilitation (CR) programs at the inpatient stage. Such cardiac determinants of rehabilitation effectiveness as the completeness of myocardial revascularization, left ventricular systolic function, the degree of myocardial microdamage during AMI development, the severity of heart rhythm and conduction disorders, as well as non-cardiac determinants in the form of anemia, obstructive pulmonary disease, diabetes mellitus, and obesity, certainly affect the functional state of the body and ET, which requires adjustments in the choice and process of rehabilitation measures.

Currently, thanks to a large evidence base, the modern aspect of using physical training (PT) in cardiac rehabilitation programs is based not only on increasing ET and developing adaptation to myocardial ischemia but also on the proven cardioprotective effect of PT [6]. This approach makes it possible to personalize cardiac rehabilitation programs by duration and intensity of PT, taking into account their effectiveness and safety, and to create individual physical training (IPT) programs for each category of patients with AMI as early as when they are transferred from the cardiac intensive care unit. The optimal use of differentiated rehabilitation programs, taking into account the cardioprotective effect of PT, ensures the stability of long-term results of the PCI performed, improves the quality of life and prognosis in this category of patients [7,8]. Considering the patient-centered approach in the treatment of patients with cardiovascular diseases, the development of personalized cardiac rehabilitation programs at the inpatient stage of treatment for patients with different completeness of myocardial revascularization during endovascular intervention and left ventricular systolic function is a particularly important clinical task. Overcoming barriers to increasing physical activity in the post-infarction period should be carried out with socio-economic and informational support from the state and the healthcare system by developing and implementing accessible physical training programs with the ability to monitor the achievement of target physical activity [9]. Predicting the construction of personalized programs based on early clinical, laboratory, and instrumental data obtained during the treatment of patients in the hospital will be the basis for recommendations on early rehabilitation after revascularization surgery, which will certainly determine the success of rehabilitation measures at subsequent stages for restoring the health and ability to work of patients, as well as reducing the risks of recurrent coronary events.

The functional state of the cardiovascular system and its reserve capabilities can be most comprehensively assessed when patients perform physical activity. The bicycle ergometry test (BET) is the most informative and quite safe. To obtain comparable results, select the optimal training regimen, and evaluate the effectiveness of rehabilitation measures, it is advisable to conduct the test at a submaximal load level. For patients capable of performing physical activity, an exercise test is the best way to assess the functional capacity of the heart and indirectly assess coronary circulation. An alternative to BET or a treadmill test for patients with incomplete myocardial revascularization and/or LVEF less than 40% may be the

6-minute walk test with a constant (single-stage) submaximal load under the patient's self-control [10].

Assessment of ET is mandatory when conducting cardiac rehabilitation programs. The exercise test is quite safe with proper patient selection (identification of absolute and relative contraindications) and compliance with all conditions for its performance. The optimal time, from a safety perspective, for performing an exercise test after AMI is not precisely defined. In an uncomplicated disease course, the exercise test is performed 2-3 days before discharge from the hospital, but not earlier than 9-10 days after the start of activation [11]. For all patients after ST-segment elevation myocardial infarction (STEMI), it is recommended to perform a graded exercise test (using an ergometer or treadmill) and, if unavailable (or contraindicated), a 6-minute walk test to assess functional ET, select optimal physical training, and monitor their effectiveness and safety [12,13,14].

Exercise tolerance, or physical performance, is an integral indicator of the body's physiological capabilities. It varies significantly between women and men, between young people and older age groups, and between individuals engaged in physical and mental labor. Within a homogeneous group, physical performance will vary depending on the patient's weight and height. R. Shephard (1969) proposed submaximal heart rate values during exercise tests depending on sex, weight, and age, which were subsequently recommended for use by the WHO Expert Committee [15,16]. Exercise testing is a key point in assessing a patient's physical performance capacity (PPC) in the CR system. Conducting an exercise test before inclusion in a PT program allows one to determine the patient's response to physical activity (PA), select the intensity of the training load based on maximum benefit and safety, and adjust the load as fitness increases. Assessing changes in PPC after completion of a physical rehabilitation program provides information about its clinical effectiveness for the patient [17].

AIM OF THE STUDY

To evaluate the safety of using exercise tests in the early stages of AMI treatment after revascularization surgery in a multidisciplinary hospital. To determine the differences in ET in patients with different degrees of myocardial revascularization and left ventricular contractile function for the subsequent construction of personalized cardiac rehabilitation programs.

MATERIALS AND METHODS

The study examined 173 patients urgently admitted to the regional vascular center of St. Petersburg State Medical Institution "Elizavetinskaya Hospital" with acute coronary syndrome (ACS). The average age was 59±11 years. The clinical characteristics of patients with ACS are presented in Table 1.

- Routine risk stratification of adverse outcomes using scales in patients with STEMI during hospitalization is not recommended due to the lack of proven effective interventions based on the results of this stratification.

Patients with STE-ACS were sent to the X-ray endovascular diagnostics and treatment department within 60 minutes for emergency coronary angiography and determination of treatment tactics. Patients with NSTE-ACS were sent to the cardiac intensive care unit. They underwent endovascular myocardial revascularization within up to 24 (72) hours depending on the risks, according to clinical guidelines.

Table 1. Clinical characteristics of patients with acute coronary syndrome

Group	Sex	Age (years)	Risk of adverse outcome (GRACE score)			Total
			Low	Medium	High	
ACS without ST-segment elevation (NSTE-ACS)	Men	57.4±9.4	24 (43%)	15 (27 %)	17 (30 %)	56 (72 %)
	Women	61.7±9.6	7 (32 %)	8 (36 %)	7 (32 %)	22 (28 %)
	Total	58.6±9.5	31 (38 %)	23 (29 %)	24 (31 %)	78 (45 %)
ACS with ST-segment elevation (STE-ACS)	Men	57.6±9.5				68 (72 %)
	Women	59.1±15.5				27 (28 %)
	Total	58.0±11.4				95 (55 %)

In the cardiac intensive care unit, patients underwent a full range of laboratory and instrumental studies. All patients underwent transthoracic echocardiography (ECHO) on an expert-class ultrasound scanner to determine left ventricular ejection fraction (according to Simpson).

Next, patients were divided into groups based on the completeness of myocardial revascularization (complete and incomplete myocardial revascularization) and LVEF (preserved and reduced LVEF). The completeness of revascularization was assessed based on control coronary angiograms after angioplasty and coronary artery stenting. The decision on the volume of revascularization was made collectively by a cardiologist and a physician of X-ray endovascular diagnostics and treatment based on the patient's condition, myocardial damage zones according to ECG and ECHO data. In cases of multivessel coronary artery disease, fractional flow reserve (FFR) or intravascular ultrasound (IVUS) was used to determine the hemodynamic significance of coronary artery stenoses. During ECHO, patients were divided into groups: with preserved LVEF (⩾50% according to Simpson) and reduced LVEF (<50% according to Simpson). The stratification of patients with AMI is presented in Table 2.

Table 2. Stratification of patients with acute myocardial infarction after myocardial revascularization

Patient Group			Men	Women	Age	Total
1	Complete revascularization	Preserved LVEF	36 (73 %)	13 (27 %)	55.8±11	49 (28%)
2	Reduced LVEF	Reduced LVEF	11 (61 %)	7 (39 %)	57±11	18 (10 %)
3	Incomplete revascularization	Preserved LVEF	47 (67 %)	23 (33 %)	60±9	70 (41%)
4	Incomplete revascularization	Reduced LVEF	29 (80 %)	7 (20 %)	58.8±12	36 (21 %)

The clinical characteristics of patients treated for AMI after emergency angioplasty and coronary artery stenting who participated in the study are presented in Table 3.

Table 3. Clinical characteristics of patients

Patient Group			Duration of CAD (years)	History of AMI	History of Revascu-larization	HTN	CHF	DM
1	Complete revascularization	Preserved LVEF	6.9±3.3	8 (16%)	5 (10%)	41 (84%)	11 (22%)	5 (10%)
2	Complete revascularization	Reduced LVEF	5.8±3.8	4 (22%)	2 (11%)	15 (83%)	6 (33%)	5 (27%)
3	Incomplete revascularization	Preserved LVEF	7.8±5.8	12 (17%)	7 (10%)	56 (80%)	19 (27%)	13 (18%)
4	Incomplete revascularization	Reduced LVEF	8.7±6	16 (44%)	5 (14%)	27 (75%)	14 (39%)	11 (31%)

After endovascular myocardial revascularization, patients received intensive care in the cardiac intensive care unit. Upon stabilization of the condition, completion of control laboratory parameters, instrumental studies, and, in the presence of somatic pathology, consultations with specialists, patients were transferred to cardiology departments. In the department, patients received the entire necessary volume of drug treatment, diagnostic studies in the presence of concomitant somatic pathology, and underwent the inpatient stage of cardiac rehabilitation according to clinical guidelines and quality criteria for medical care in AMI.

To select tactics for expanding the patient's motor regimen, prescribing gradually increasing loads during rehabilitation, before discharging the patient from the hospital, transferring to a rehabilitation department or a specialized sanatorium, the rehabilitation classification of the severity of the clinical condition was used (Aronov D.M., 1983), Table 4.

Table 4. Rehabilitation classification of the severity of the clinical condition of patients with AMI (according to Aronov D.M., 1983; modification 2014)

Severity Groups MI	Signs
First (Mild)	· No signs of heart failure (HF) · No symptoms of myocardial ischemia and angina · No complex heart rhythm and conduction disorders · Adequate response when expanding the motor activity regimen
Second (Moderate)	· HF class II according to Killip T., Kimball J. (1967) · AV block above I degree in inferior MI · AV block I degree in anterior MI or against the background of bundle branch block · Resolved paroxysmal rhythm disorders, except for ventricular paroxysmal tachycardia · Permanent form of atrial fibrillation · Wandering atrial pacemaker · Frequent extrasystole (more than 1 extrasystole per min), or class III-IV according to Lown, prolonged (throughout the observation period) or frequently recurring episodes · Dressler's syndrome · Arterial hypertension requiring additional treatment

Third (Severe)	· Acute HF class III-IV according to Killip T., Kimball J. (1967) · Chronic HF resistant to treatment · Angina or signs of myocardial ischemia on ECG during low physical activity · Slow evolution of the ST segment or its absence, new ischemic or focal changes on ECG · Complex ventricular rhythm disorders at rest or during exercise · Acute cardiac aneurysm · Thromboendocarditis · Any severe complications and acute conditions requiring specialized treatment · Combination of 3 or more complications of the second group

In the study to determine ET during exercise tests after revascularization surgery, only patients with mild and moderate severity groups of AMI according to the rehabilitation classification were selected. Also, clinical signs and laboratory-instrumental data over time determined the duration of inpatient treatment. Stratification of patients by severity groups and the duration of inpatient treatment is presented in Table 5.

Table 5. Stratification of patients by severity groups

Patient Group			Severity Groups of MI		Total	Average duration of inpatient treatment (bed/days)
			First (Mild), number	Second (Moderate), number		
1	Complete revascularization	Preserved LVEF	38 (78 %)	11 (22 %)	49	9
2	Complete revascularization	Reduced LVEF	8 (44 %)	10 (56 %)	18	11
3	Incomplete revascularization	Preserved LVEF	45 (64 %)	25 (36 %)	70	11
4	Incomplete revascularization	Reduced LVEF	7 (19 %)	29 (81 %)	36	12

On the eve of, or on the day of, the patient's discharge from the hospital, transfer to an inpatient rehabilitation department or a specialized sanatorium, stress tests were performed. In the morning, before taking medications, patients underwent a six-minute walk test (6MWT) according to the standard method. After a long rest, in the functional diagnostics department, patients underwent BET (submaximal or symptom-limited stress test) on a vertical bicycle ergometer. The results of the stress tests were recorded in a specially developed standardized form.

Exercise tolerance in each group of examined patients was determined based on the submaximal heart rate during BET, calculated using the formula by Yakovlev G.M. (1979), which, in our opinion, most objectively allows for assessing ET in patients with AMI after endovascular myocardial revascularization:

Submaximal HR = Baseline HR + K x (215 - Baseline HR - age), where "K" is the coefficient; (in our patients – with CAD and post-infarction cardiosclerosis, it is 0.5; for patients with angina, it is 0.7).

STUDY RESULTS

The performance of stress tests in all study groups was: 6MWT – 100%, BET – 94%. 11 patients were unable to perform the exercise test on a bicycle ergometer due to musculoskeletal pathology, body weight over 130 kg, or decompensation of concomitant somatic pathology. The pathological conditions that developed during stress tests in patients in the early stages of AMI and the frequency of their occurrence are presented in Table 6.

Table 6. Pathological conditions during stress tests

Patient Group			Stress Test	Angina on effort	Heart rhythm disturbance	Total
1	Complete revascularization	Preserved LVEF	6MWT	0	0	0
			BET	0	1	1
2	Complete revascularization	Reduced LVEF	6MWT	0	0	0
			BET	1	2	3
3	Incomplete revascularization	Preserved LVEF	6MWT	0	0	0
			BET	2	1	3
4	Incomplete revascularization	Reduced LVEF	6MWT	1	1	2
			BET	2	2	4

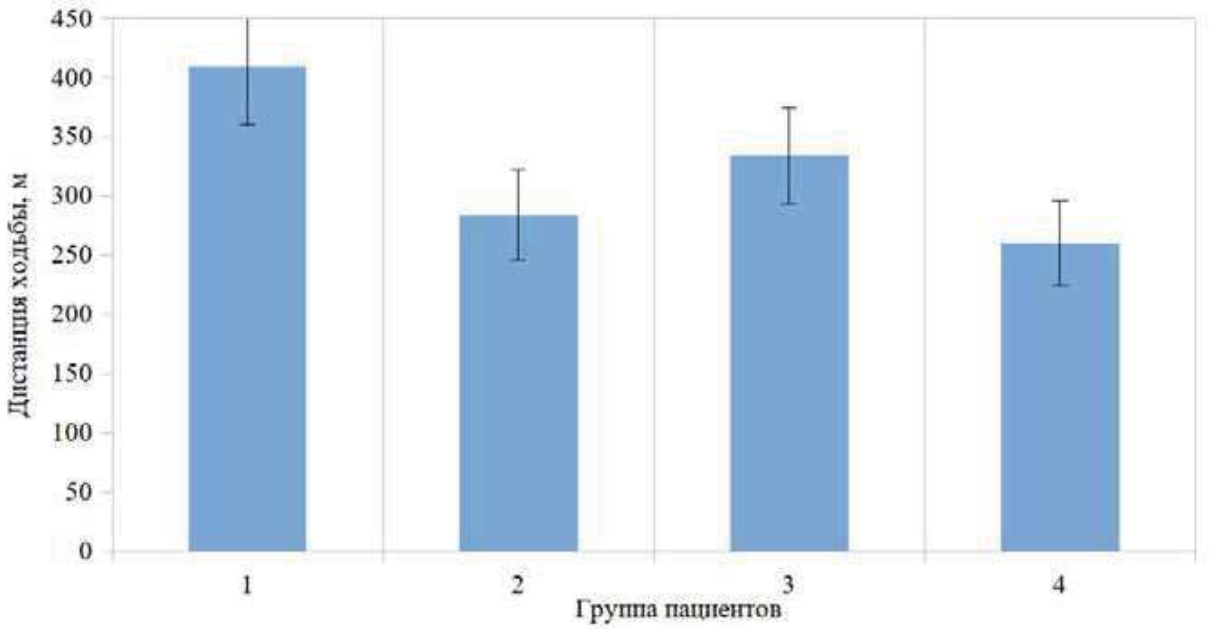
Thus, during stress tests performed upon discharge of patients with AMI after endovascular myocardial revascularization, a total of 13 (7.5%) transient pathological conditions were registered, probably related to physical activity, which did not require emergency care or therapy adjustment and did not lead to an increase in the duration of the current hospitalization. Accordingly, the performance of symptom-limited stress tests to assess ET by qualified medical personnel with proper patient selection is a safe method of functional diagnosis.

The 6MWT revealed significant differences in indicators between the study groups, presented in Table 7.

Table 7. Results of the 6MWT in the groups of studied patients

Patient Group			Distance walked, m	Load intensity (Borg scale)	Severity of dyspnea (Borg scale)
1	Complete revascularization	Preserved LVEF	409±49	1,9±0,7	1,8±0,6
2	Complete revascularization	Reduced LVEF	284±38	3,1±0,7	3,2±0,7
3	Incomplete revascularization	Preserved LVEF	334±41	2,6±0,6	2,5±0,6
4	Incomplete revascularization	Reduced LVEF	260±36	3,3±0,6	3,5±0,8

Differences in the distance walked by patients during the SMWT by groups depending on the completeness of myocardial revascularization during endovascular intervention and LVEF are shown in Graph 1.



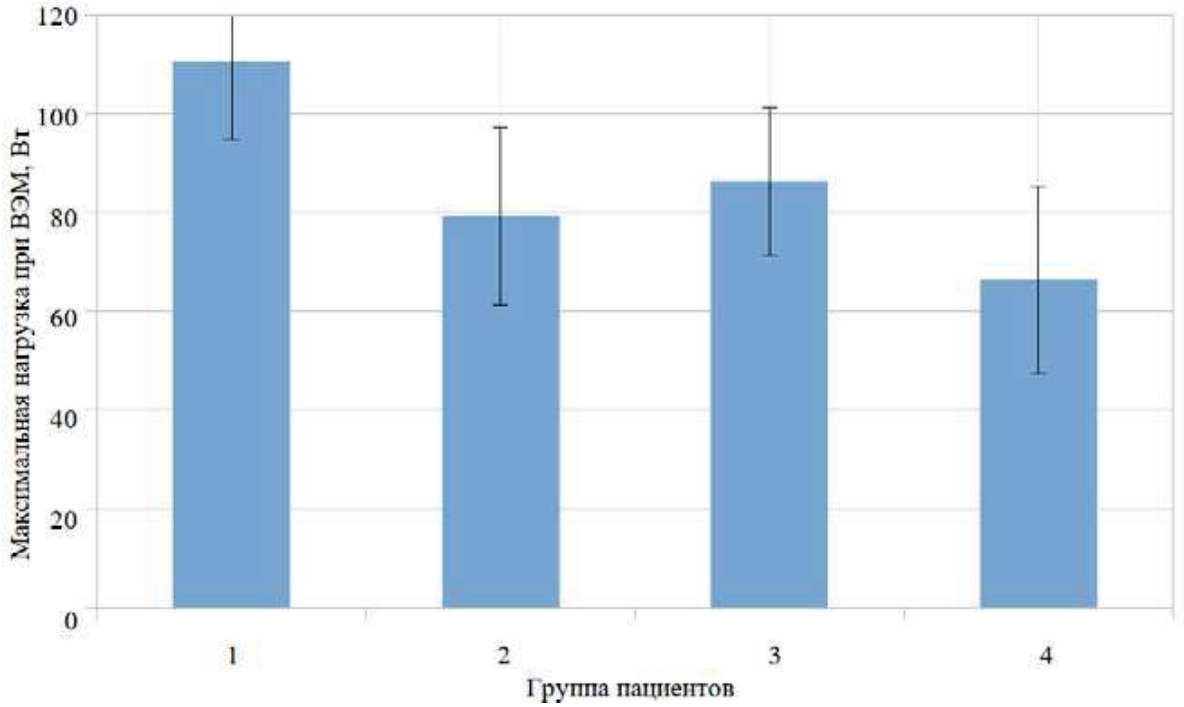
Graph 1. Walking distance during the SMWT in the studied patient groups

During symptom-limited BET, differences related to the volume of myocardial revascularization during endovascular intervention and left ventricular myocardial contractile function were also revealed. The main indicators of BET are presented in Table 8.

Table 8. Results of BET in the groups of studied patients

Patient Group			Maximum load, W	Load duration, min	Maximum HR during VST, bpm	Threshold power, W/kg
1	Complete revascularization	Preserved LVEF	110,7±16	12,3±0,4	121±4	1,3±0,4
2	Complete revascularization	Reduced LVEF	79,2±18	9,2±0,5	109±5	0,9±0,3
3	Incomplete revascularization	Preserved LVEF	86,3±15	10,4±0,6	114±4	1,0±0,3
4	Incomplete revascularization	Reduced LVEF	66,4±19	6,2±0,6	103±6	0,65±0,2

Differences in the maximum performed load during BET by groups depending on the completeness of myocardial revascularization during endovascular intervention and LVEF are shown in Graph 2.



Graph 2. Maximum load during BET in the studied patient groups

Based on the results of the performed BET in patients with AMI after endovascular myocardial revascularization upon discharge from the hospital or transfer to a rehabilitation department, an assessment of ST was carried out, allowing for the stratification of patients in the study groups. ST during BET is presented in Table 9.

Table 9. Exercise tolerance during bicycle ergometry test

Patient Group			Exercise tolerance, number of patients			Total
			High	Medium	Low	
1	Complete revascularization	Preserved LVEF	12 (25%)	31 (66%)	4 (9%)	47
2	Complete revascularization	Reduced LVEF	0	4 (24%)	13 (76%)	17
3	Incomplete revascularization	Preserved LVEF	4 (7%)	27 (40%)	35 (53%)	66
4	Incomplete revascularization	Reduced LVEF	0	2 (6%)	30 (94%)	32

Conclusion

Thus, BET during stress tests in patients with AMI after angioplasty and coronary artery stenting differs depending on the completeness of revascularization and depends to a greater

extent on the contractile function of the left ventricular myocardium, which is an important functional indicator for choosing the intensity and duration of PT during personalized CR at the inpatient stage. Knowledge of these differences will allow for early prediction of the effectiveness of rehabilitation measures and a differentiated approach in their implementation. A personalized approach based on clear clinical, laboratory, and instrumental data will improve the cardiac rehabilitation system for patients after AMI in general.

REFERENCES

1. Aronov, D. M., Bubnova, M. G., Krasnitsky, V. B. (2015). New approaches to rehabilitation and secondary prevention in patients with ST-segment elevation acute myocardial infarction. Kardiologiia, 55(12), 125-132.
2. Kontsevaya, A.V., Bates, K., Goryachkin, E.A., et al. (2018). Inpatient phase of myocardial infarction treatment in 13 regions of the Russian Federation according to the results of an international study. Rational Pharmacotherapy in Cardiology, 14(4), 474-487.
3. Guazzi, M., Adams, V., Conraads, V., et al. (2012). EACPR/AHA Scientific Statement. Clinical recommendations for cardiopulmonary exercise testing data assessment in specific patient populations. Circulation, 126(18).
4. Drapkina, O.M., Novikova, N.K., Dzhioeva, O.N. (2020). Methodological recommendations: "Modern possibilities and prospects of complex physical activity in patients with cardiovascular pathology". Preventive Medicine, 23(3-2), 61-119.
5. Adams, V., Linke, A. (2019). Impact of exercise training on cardiovascular disease and risk. Biochimica et Biophysica Acta (BBA) - Molecular Basis of Disease, 1865(4), 728-734.
6. Larina, V.N., Akhmatova, F.D., Arakelov, S.E., Mokhov, A.E., Doronina, I.M., Denisova, N.N. (2020). Modern strategies of cardiac rehabilitation after myocardial infarction and percutaneous coronary intervention. Kardiologiia, 60(3), 111-118.
7. Lyamina, N.P., Karpova, E.S., Karpova, E.S., Bizyaeva, E.A. (2014). Physical training in cardiac rehabilitation and prevention in patients with coronary artery disease after percutaneous coronary interventions: limits of effectiveness and safety. Russian Journal of Cardiology, (6), 93-98.
8. Fletcher, G.F., Ades, P.A., Kligfield, P., et al. (2013). Exercise standards for testing and training: a scientific statement from the American Heart Association. Circulation, 128(8), 873-934.
9. Sedykh, D.Yu., Khryachkova, O.N., Krivoshapova, K.E., Tsygankova, D.P. (2022). Unsolved issues of increasing physical activity after myocardial infarction. Russian Journal of Cardiology, 27(2S), 4828.
10. 2018 ESC/EACTS Guidelines on myocardial revascularization. (2019). Russian Journal of Cardiology, (8), 151-226.
11. Aronov, D. M., Bubnova, M. G., Barbarash, O. L., et al. (2014). ST-segment elevation acute myocardial infarction: rehabilitation and secondary prevention. CardioSomatics, (S1), 5-41.
12. Budnevsky, A.V., Kravchenko, A.Ya., Tokmachev, R.E., Chernik, T.A., Tokmachev, E.V., Letnikova, Yu.B. (2020). Diagnostic, prognostic and therapeutic possibilities of using the 6-minute walk test in patients with chronic heart failure. Cardiovascular Therapy and Prevention, 19(6), 2460.
13. Averkov, O.V., Arutyunyan, G.K., Duplyakov, D.V., et al. (2025). ST-segment elevation acute myocardial infarction. Clinical guidelines 2024. Russian Journal of Cardiology, 30(3), 121-207.
14. Averkov, O.V., Arutyunyan, G.K., Duplyakov, D.V., et al. (2025). Non-ST-segment elevation acute coronary syndrome. Clinical guidelines 2024. Russian Journal of Cardiology, 30(5), 127-216.
15. Gadzhieva, L.R., Tkachenko, S.B., Palchenkova, M.V. (2015). Functional ECG tests using graded physical activity: a textbook. Moscow: RMAPE.
16. Ushakova, L.Yu., Vertinsky, E.A., Shtonda, M.V., Semenenkov, I.I. (2021). Exercise tests in the diagnosis of coronary heart disease, testing of patients. Emergency Cardiology and Cardiovascular Risks, 5(1), 1247-1256.
17. Bubnova, M.G., Persiyanova-Dubrova, A.L. (2020). The use of the six-minute walk test in cardiac rehabilitation. Cardiovascular Therapy and Prevention, 19 (4), 2561.

Received / Получено 02.01.2026
Revised / Пересмотрено 22.01.2026
Accepted / Принято 20.02.2026