Dynamic Characteristics of Heart Rate and Systolic Blood Pressure at Early Exercise Test after Myocardial Infarction in Predicting the Life Expectancy

KAMILĖ LAIMUTĖ BLOZNELIENĖ, REMIGIJUS ŽALIŪNAS, JULIJA BRAŽDŽIONYTĖ, INA BLUŽAITĖ, REGINA GRYBAUSKIENĖ, LAIMA TALIJŪNIENĖ, GABIJA PUNDZIŪTĖ

From Kaunas University of Medicine Institute of Cardiology, Kaunas University of Medicine Clinic of Cardiology, Kaunas, Lithuania

BLOZNELIENĖ ET AL.: ***Dynamic Characteristics of Heart Rate and Systolic Blood Pressure at Early Exercise Test after Myocardial Infarction in Predicting the Life Expectancy.*** *During 11 years period submaximal exercise testing within 3 weeks of acute myocardial infarction was performed with 894 patients. Exercise induced ST segment depression appears to have prognostic significance of subsequent development of fatal coronary events at 6, 12, 24 months and 11 years post infarction. At follow-up at 2 years post infarction in the non survivors group there were only 45.2% exercise induced ST segment depression. This shows, that prognostic importance of ST depression is insufficient and demands of research of more consistent signs. The cardiovascular response to exercise was interpreted as transiting process of the self-regulation of cardiovascular system, and the new predictive signs were found on the basis of heart rate and systolic blood pressure curves during the exercise and after it. The prognostic value of these signs were established. The combined use both the new predictive signs and the usual data of early exercise test shows the high predictive possibility of test – the early cardiac death was predicted in 80% of cases. The patients after myocardial infarction can be divided into relative high and low-risk groups for subsequent cardiac events if all information available on the exercise test is used. (J HK Coll Cardiol 2004;12:70-74)*

Early exercise test, myocardial infarction

摘要

在11年期間我們對894位三周內急性心肌梗塞的病人進行了亞極量的運動測試。運動將引起ST段壓低，這似乎對於梗塞後6、12、24個月和11年間致命性的冠心病事件的發展具有顯著的預後意義。在心肌梗塞後2年的隨訪中，非存活組中只有45.2%的病人運動後出現ST段壓低。這表明ST段壓低的預後重要性尚不充分，還需要對相關徵象進行研究。對於運動的心血管反應可以理解爲心血管系統的自我調節過程，新的有預測意義的徵象是基於運動中和運動後心率和收縮壓變化曲線發現而得的。這些具有預後價值意義的指標已經確立。聯合運用這些新的早期運動測試預測指標和常用資料將有著很高的預見性，它能夠預測80%病例的早期心源性死亡。如果所有運動測試的資訊均能獲得，對於後續的心臟事件心肌梗塞後病人能夠劃分爲相對高危組和低危組。

關鍵詞：早期運動測試　心肌梗塞

Address for reprints: Dr. habil. Kamilė Laimutė Bloznelienė
Kaunas University of Medicine Institute of Cardiology, Sukileliu 17, LT-3007, Kaunas, Lithuania

Tel: (370) 37 302871; Fax: (370) 37 302872

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Introduction

Despite the rise and spread of new diagnostic methods, exercise electrocardiography still remains the cornerstone of non-invasive evaluation and is almost uniformly performed after myocardial infarction (MI).[1]

This test is usually performed (in case of absence of contraindications) to all the patients after MI before the discharge. The prognostic value of the exercise test is not enough investigated despite of the high percentage of the persons dying suddenly after MI. The evaluation of depression of ST-segment in exercise test in predicting the prognosis after MI is not uniform.[1-3] According to the literature and our data, sudden death during 6 months after MI is closely related to the life-threatening arrhythmias, detected in early exercise test after MI. This relation could not be established after MI later.[4,5] It is considered the value of the exercise-induced QT dispersion (as a sign of ventricular depolarisation inhomogeneity) in predicting ventricular arrhythmias and sudden cardiac death.[6] The data are contradictory in assessing which exercise test parameters are related with survival over 6 months after MI.[7] Some authors regard to ST-depression as a borderline parameter and the main attention pay to the workload, which was obtained during the exercise. This sign is closely related to the survival over 10 as well as 15 years after MI.[8] Heart rate (HR) and blood pressure (BP) changes represent the cardiovascular response to the exercise. The aim of our study was to evaluate the prognostic capability of these signs and to design the prognostic system capable to pick up patients with high risk of coronary death during 2 years time after MI, using the data of early exercise testing.

Patients and Methods

A total of 894 patients (aged 50.68±9.29 years; 827/92.5% males and 67/7.5% females) admitted to Kaunas Medical University Hospital have met the eligibility criteria and were put through submaximal exercise testing within 3 weeks of the onset of acute MI. Cases of noncardiac deaths, patients living outside Kaunas or those subjected to coronary bypass surgery were excluded from the further analysis. Kaunas Acute Myocardial Infarction Register was used for survival (12 months - 11 years) analysis. At the end of 2 years after MI there were 426 survivors (group I) and 42 cases of cardiac death (group II). After 11 years there were 98 coronary deaths.

The submaximal exercise testing (25 W incremental loading every 3 minutes) was performed within 3 weeks after acute myocardial infarction. A 12 lead ECG was continuously monitored throughout the test and 10 minutes after it. A blood pressure was measured before the exercise test and every minute during and 10 min. after the test. The occurence of significant anginal pain, ventricular tachycardia, major conduction abnormalities, ST-depression >2 mm, limiting symptoms (such as dyspnoea, dizziness, fatigue, cramp in legs, etc.), an excessive increase (above 230 mmHg) or decrease (>30 mmHg) in systolic blood pressure were regarded as interruption criteria. Both ST depression in one or more leads, excluding aVR and V1, and ST elevation in leads without pathological Q waves were considered. The exercise-induced angina pectoris and/or the presence of horizontal or downsloping ST depression of 1 mm measured 80 ms after J point and of ST elevation of 1 mm measured 40 ms after the J point were regarded as positive criteria. Positive was defined as low-threshold if occuring at workload <75 W (450 kgm/min).

Results

Results of exercise testing 3 weeks after MI were as follows: mean peak workload differed significantly between the two groups: 44.5±0.9 W (267±5.4 kgm/min) in group I and 34.2±3.5 W (205.2±21 kgm/min) in group II ($p<0.01$). The exercise testing elicited angina and/or ST depression of >1 mm (ischemic response) in 132 (31%) patients of group I and in 24 (57.1%) patients of group II ($p<0.01$). ST depression of >1 mm was detected in 33 (7.8%) and in 19 (45.2%) cases respectively ($p<0.01$). Exercise test positive ST-segment only was detected in 17 (4 %) patients of group I and in 9 (21.4%) patients of group II ($p<0.01$). Indicators for electrical instability (exercise induced serious ventricular arrhythmias) showed no significant differences between the groups in 21 (4.9%) patients of group I and in 4 (9.5%) patients of group II ($p>0.3$). The patients of group I had better exercise capacity and ST depression was registered only in 7.8 % of patients as compared with 45.2% of patients of group II.

Our patients were in good functional state at entry (no patients had a contraindication to exercise); nonetheless, there were 8.5% of cardiac deaths within the first two years among the acute MI survivors. Among those dying within the first two years, only 45.2% had the exercise-induced ST segment depression. This shows that the prognostic value of ST depression is not sufficient and demands research of more consistent signs.

The cardiovascular response to exercise was interpreted as a transition process in the self-regulation of cardiovascular system (system's reaction to the stress). The survival was predicted by the shape of heart rate (HR) and systolic blood pressure (BP) curves (their dynamic characteristics) during exercise testing and after it. The signs specific to cardiovascular response to exertion were selected as follows: (1) the extent of systolic BP changes at the beginning of the exercise testing; (2) the extent of HR changes at the beginning of the exercise testing; (3) the character of HR changes one minute after the exercise discontinuation; (4) the character of systolic BP changes one minute after the exercise discontinuation (5) the correlation strength between the HR and systolic BP curves within the exercise test; (6) the character of HR curves at rest after the exercise; (7) the character of systolic BP curves at rest after the exercise; (8) the character of HR changes at the last minute of exercise; (9) the character of systolic BP changes at the last minute of exercise. The prognostic value of these signs was determined. A combined use of both, the usual data (indicators for residual myocardial ischaemia) and the new signs – dynamic characteristics of HR and BP curves considerably increased the predictive power of the test. Each sign included several manifestations. For example, the character of systolic BP and HR changes at the beginning of the exercise testing may be manifested by the different degrees of change intensity, BP and HR may increase and decrease, with or without delay. All these specific features are described as characteristic of sign. All the data obtained in exercise testing in the early period of MI was divided in two parts. One, named group C, was used as a learning assembly. In this C group we chose all cases of death in 0.5 year after MI and named this group A; all cases of death in the period between 0.5 and 2 years after MI and named this group B. So the remaining group D included the cases with no death in the period of 2 years after MI. D=C-(A+B).

Then the prognostic value in prediction of the high risk of coronary death of characteristics of signs was determined. For this purpose we computed the frequency rate of each characteristic of all the signs in group A, A+B, C and D, and denoted frequency rate of x-characteristic of i-sign in the group A as ${}^{i}\varphi_{A}(x)$, in the group A+B as ${}^{i}\varphi_{A+B}(x)$, in the group C as ${}^{i}\varphi_{C}(x)$ and in the group D as ${}^{i}\varphi_{D}(x)$. If the frequency rate of x-characteristic is the same or nearly the same in group A as in group C or D, this characteristic has no prognostic value. In contrast, if the value of frequency rate in group A is considerably greater in comparison with C or D, this characteristic has higher prognostic value, higher informativity. We denote informativity as a relation:

$$ {}^{i}\sigma_{A}(x) = \frac{{}^{i}\varphi_{A}(x)}{{}^{i}\varphi_{D}(x)} \; ; \quad {}^{i}\sigma_{A+B}(x) = \frac{{}^{i}\varphi_{A+B}(x)}{{}^{i}\varphi_{D}(x)} \; ; $$

We reject $\sigma(x)$ if $\sigma(x) < 1.5$.

We denote the prognostic power of characteristic of sign by following expressions:

$$ {}^{i}\xi_{A}(x) = 10 \cdot {}^{i}\sigma_{A}(x) \cdot {}^{i}\varphi_{A}(x) $$

$$ {}^{i}\xi_{A+B}(x) = 10 \cdot {}^{i}\sigma_{A+B}(x) \cdot {}^{i}\varphi_{A+B}(x) $$

After evaluation of separate characteristics of sign, the prognostic power of sign is determined as a set of selected prognostic powers of characteristics of this sign

$$ P_i = \sum_{j=1}^{n} {}^{i}\xi\,(x_j) $$

x_j, x_l,... x_n are denominations of characteristics of sign.

An example (for sign SAFP - the extent of systolic BP changes at the beginning of exercise test):

If SAFP (x = D1), then ${}^{1}\xi_{A}(D1) = 4.4$
SAFP (x = D2), then ${}^{1}\xi_{A}(D2) = 3.5$
SAFP (x = D5), then ${}^{1}\xi_{A}(D5) = 1.9$
SAFP (x = m), then ${}^{1}\xi_{A}(Dm) = 2.6$

Here D1, D2,... m - are concrete manifestations (characteristics) of sign.

The same method is used for evaluation of other signs:

$P_2, P_3, ...P_n$

The full prognostic power

$$\Pi_z = \sum_{j=1}^{n} P_i^A$$

n - the number of used signs, z - identificator of individual.

In accordance with this method, a programme for the computer was developed, and with this programme the values of

$$\Pi_z^A \text{ and } \Pi_z^{A+B}$$

for each member of group "C " were estimated.

It was found that with increase of numeral quantity of prognostic power the risk of coronary death after MI increases.

After computation of prognostic power of each member in groups A, A+B, C and D, the arithmetical mean of prognostic power of each group V_A^d, V_{A+B}^d, V_C^d and V_D^d was estimated (obtained):

$$V_A = 28.66; V_{A+B} = 31.05; V_C = 23.45; V_D = 21.0.$$

These quantities may by used as criteria to pick up the patients with high risk of coronary death. The same method was applied for evaluation of prognostic values of widely accepted data of early exercise testing. The combined use of both the widely accepted data of early exercise testing and the dynamic characteristics of HR and systolic BP considerably increased the predictive power of the test. Computation of arithmetical mean of prognostic power gave following quantities

$$V_A^b = 40.69; V_{A+B}^b = 39.83; V_C^b = 27.55; V_D^b = 26.82.$$

After these investigations with the learning assembly and determination of prognostic power of signs, an examination on the other part of data of early exercise testing was performed It demonstrate that early cardiac deaths were correctly predicted in 80% of cases.

Discussion

It is known that the double product (BPxHR/100) attained during the exercise test represents the survival prognosis and the decrease of BP during the exercise correlates with unfavourable outcomes.[5] According to our data, exercise induced hypotension was registered more frequently in the group of survivors.[9] The hypotension was established in 8.6% of the survivors and in 7.16% among those dying within the first 6 months after MI. In the group of 1-year survivors after MI, exercise hypotension was established in 9% of patients and in non-survivors – in 3.1% of cases. Two years after MI the results were 9.2% and 2.4% respectively. Hypotension in early exercise test was detected in 10% of patients in the group of 10 years survivors and in 5.1% of patients dying during this period after MI. Our patients undergoing early exercise test after MI were in relative good physical condition, without any contraindications for the test. In this case we can explain the relative rare hypotension cases in our early exercise tests after MI and no established correlation to the unfavourable outcomes. According to our data, dynamic of BP and HR during the exercise and after it were related to survival after MI.

It is important to pay attention to such easy detectable marker of sudden cardiac death – absence of T-wave pseudonormalisation during the early exercise test after MI. This sign is not enough investigated. There is an opinion,[10] that this could be related to the absence of the metabolic myocardial activity. Necrotic myocardium has no metabolic and electrical activity, so in these cases negative T-waves can not undergo the changes (absence of pseudonormalisation). Our data revealed, that in the group of 11 patients dying suddenly during the first 6 months after MI, all of them had negative T-waves in the zone of infarction. Ten (90.9%) of them had no T-pseudonormalisation pattern during the exercise test. Negative T-waves at the third week after MI were detected in 58 (66%) of 87 patients dying during 10 years after MI. The early exercise test did not induce T-pseudonormalisation in 21 (36.2%) of these patients (significantly lower (p<0.01) as compared to the death cases during the first 6 months after MI).[11] Thus, our data showed, that the absence of T-wave pseudonormalisation during the early exercise test after MI may predict early sudden death after MI.

Conclusion

In conclusion, patients after MI can be divided into relative high and low-risk groups for subsequent cardiac events if all information available on the exercise test is used. The use of the dynamic characteristic of heart rate and systolic blood pressure considerably increase the predictive power of the test; the early cardiac deaths being correctly predicted in 80% of cases.

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