Exercise Stress Body Surface Isopotential Map in Patients with Coronary Artery Disease: Comparison with Coronary Angiographic and Stress Myocardial Perfusion Scintigraphic Findings

MASATOSHI WADA, M.D., KENZO KANEKO, M.D., HIROAKI TESHIGAWARA, M.D.
TAKESHI KONDO, M.D., SUSUMU OHASHI, M.D., YUTAKA MIYAGI, M.D.
MASANORI NOMURA, M.D., SATOSHI OKAJIMA, M.D.
HITOSHI HISHIDA, M.D., AKIRA TAKEUCHI, M.D.
AND YASUSHI MIZUNO, M.D.

To locate the ischemic area in 22 patients with angina pectoris, exercise stress body surface isopotential maps (MAPs) were assessed and compared with coronary angiography and myocardial stress scintigraphy. Taking coronary angiographic findings into consideration, 4 types of ischemic MAP responses, i.e., septum and anterior, lateral, inferior, and posterior wall ischemia were postulated. Sensitivity of stress MAP was 71% for the average and more than stress imaging. Specificity of stress MAP was 46% for the average and less than stress imaging.

IN order to evaluate the ability of exercise stress body surface isopotential maps (stress MAPs) to locate an ischemic area, stress MAPs were compared with exercise stress myocardial scintigraphy (stress RI) and selective coronary arteriography (CAG). Potentials during ST segments were analyzed in this study.

MATERIALS AND METHODS

Stress MAP and Stress RI were performed on 22 patients. Those with ischemic heart disease associated with valvular, cardiomyopathic or congenital heart disease were all excluded. CAG was performed on 8 patients. More than 75% stenosis of coronary artery was considered to be

a significant lesion. There were 3 patients with three-vessel disease, 2 patients with two-vessel disease and 3 patients with one-vessel disease.

Exercise Stress Testing

Patients were exercised in the supine position using a electrical braked bicycle ergometer.¹ Load was set at 25 watts, and then increased by 25 watts every 3 minutes until one of the following end points appeared: 1) anginal chest pain, 2) fatigue, 3) arrhythmias, 4) ST depression; $ST_j \leq -0.2$ mV and $QX/QT \geq 50\%$, horizontal depression or sagging depression,² 5) target heart rate (85% of age predicted maximal heart rate). When one of the above end points appeared, $^{201}\text{TlCl}$ was injected intravenously and exercise stress was continued for additional one minute at the same load. Throughout the exercise, the standard 12-lead ECG and blood pressure were monitored. Hemodynamic changes (systolic blood pressure and heart rate) at rest and after exercise stress are shown in Table I.

Key Words:

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Department of Medicine, Fujita Gakuen University School of Medicine, Toyoake, Aichi 470-11 Japan

Fig.2. Localization of ischemia based on location of ischemic responses in stress MAPs.

Body Surface Isopotential Maps

Body surface isopotential maps were constructed of synchronous unipolar ECG recordings from 87 lead points over the chest surface using a Chunichi Denshi Heart Potential Mapper.^{3,4} Data were computer-processed and the potentials were plotted as an isopotential map at 4 msec intervals during one heart beat. MAPs were recorded before and immediately after the exercise stress.

Myocardial Perfusion Imaging

Exercise imaging was begun immediately after the termination of postexercise MAP recording. Images in the resting state were obtained 4 hours after the exercise test. Both rest and stress images were recorded in the anterior, 45° left anterior oblique, left lateral and 45° right anterior oblique views.⁵

RESULTS AND DISCUSSION

Interpretation of Exercise Stress MAP

If poststress MAP revealed on area showing the ST depression of -0.2 mV or less at STj and an area showing the ST depression of -0.1 mV or less at 0.06 and 0.08 sec after STj, the ischemic MAP response was regarded as positive.

Figure 1 shows the stress MAP in a patient with effort angina. This patient had an isolated 90% (segment 6) left anterior descending artery (LAD) stenosis, and developed angina by exercise testing. The MAP was normal at rest. The characteristic patterns of the postexercise MAP of this patient are negative potential ($\approx -0.2\text{ mV}$) area (white area) covering a left and lower portion of anterior chest surface at STj point, and a positive potential ($\geq 0\text{ mV}$) area (gray area) extending over the right upper anterior chest surface at STj point, and a positive potential ($\geq +0.1\text{ mV}$) area appearing on the middle anterior chest surface at 60 and 80 msec after

Fig.3. Stress MAP showing inferior wall ischemia. Postexercise recordings.

STj point.

Another patient also had an isolated 90% left anterior descending artery (segment 6) stenosis, and developed angina by exercise testing. In the recordings at 60 and 80 msec after STj, positive potentials ($\geq +0.1$ mV) covered upper half of anterior chest surface.

We regarded these types of stress MAP as showing septum and anterior wall ischemia. The hypoperfusion and/or defect zone of stress RI also suggested septum and anterior wall ischemia.

Based on the findings of above 2 patients with an isolated 90% (segment 6) LAD stenosis, and taking account of other patients with different coronary artery diseases, we postulated a stress MAP criterion of septum and anterior wall ischemia. The feature of septum and anterior wall ischemia is a positive potential ($\geq +0.1$ mV) area at 60 and/or 80 msec after STj which extends over the upper two thirds of the right anterior chest surface (Fig. 2).^{6,7}

Figure 3 shows a patient with effort angina. This patient had an isolated 75% (segment 2) right coronary artery (RAD) stenosis, and developed angina with exercise testing. The MAP was normal at rest.

The characteristic pattern of the postexercise stress MAP of this patient was a negative potential (≤ -0.2 mV) area covering lower half of the MAP which persisted from STj to 80 msec after STj.

Based on the MAP of this patient with RAD stenosis, we postulated a MAP criterion of inferior wall ischemia.

The feature of inferior wall ischemia is negative potentials (≤ -0.2 mV) covering lower one third of the MAP from STj to 80 msec after STj (Fig. 2).

On the assumption that ischemic stress MAP responses of the lateral and posterior wall result from left circumflex (LCX) and RAD diseases, respectively, we postulated stress MAP criteria of lateral and posterior wall ischemia (Fig. 2).

The feature of lateral wall ischemia is negative potentials (≤ -0.2 mV) covering the upper two thirds of the left antero-lateral chest surface from STj to 80 msec after STj.

The feature of posterior wall ischemia is negative potentials (≤ -0.2 mV) covering the posterior chest surface from STj to 80 msec after STj.

Interpretation of Stress RI

The myocardial scintigrams were divided into 5 segments: septal, anterior, lateral, inferior and

posterior. All of the exercise studies were compared with rest studies, and 5 segments were analyzed for the appearance of new defects and/or hypoperfusion after exercise.

Ischemic defects in the septum and anterior wall were interpreted as indicative of LAD disease, those in the lateral wall, of LCX disease, and those in the inferior and posterior wall, of RAD disease.

Seventeen of 22 patients showed ischemic stress MAP responses. The other patients showed negative ischemic stress MAP responses and negative imaging.^{8,9}

Six of 17 patients who showed ischemic stress MAP responses had normal myocardial scintigrams at rest and after exercise.

Correlation of Stress MAPs with CAG Findings (Table II)

We postulated that the septum, and anterior wall were supplied with LAD, a lateral wall, with LAD and LCX, inferior and posterior walls, with RAD.

The ischemic area after exercise were located by stress MAPs and compared with CAG findings based on these assumptions (Table II).

Sensitivity of stress MAPs to CAG was 25 of 35 patients (71%) for a total group. Seven of 7 patients (100%) for septum, 6 of 7 patients (86%) for anterior wall, 3 of 7 patients (42%) and one of 2 patients (50%) for lateral wall, 4 of 6 patients (67%) for inferior wall, 4 of 6 patients (67%) for posterior wall.

Specificity of stress MAPs to CAG was 6 of 13 patients (46%) for a total group.

Whereas average sensitivity of RI to CAG was 9 of 35 patients (26%). Specificity of stress MAPs to CAG was 6 of 13 patients (46%) for the average and was lower than that of RI to CAG which was 100%.

REFERENCES

1. WADA M, KONDO T, TESHIGAWARA H, KANEKO K, OHASHI S, HISHIDA H, TAKEUCHI A, HISADA S, MIZUNO Y: Exercise stress body surface isopotential map in patients with coronary artery disease: Comparison with coronary angiography and myocardial stress perfusion scintigraphy. *Jpn Circul J* 44: 482, 1980
2. AHA COMMITTEE REPORT: A reporting system on patients evaluated for coronary artery disease. *Circulation* 51: 4, A5, 1975
3. YAMADA K, TOYAMA J, WADA M, SUGIYAMA S, SUGENOYA J, TOYOSHIMA H, MIZUNO Y, KOBAYASHI T, OKAJIMA M: Body surface isopotential mapping in Wolff-Parkinson-White

- syndrome: Noninvasive method to determine the localization of the accessory atrio ventricular pathway. *Am Heart J* 90: 721, 1975
4. WADA M: Relation between body surface isopotential map of myocardial infarction and coronary angiographic findings. *Jpn Circul J* 41: 1051, 1977
 5. BAILEY TK, GRIFFITH LSC, ROULEARN J: Thallium 201 myocardial perfusion imaging at rest and during exercise. *Circulation* 55: 79, 1977
 6. FORTUIN NJ, FRIESINGER GC: Exercise induced S-T segment elevation: Clinical, electrocardiographic and arteriographic studies in twelve patients. *Am J Med* 49: 459, 1970
 7. DUNN RF, FREEDMAN B, BAILEY IK, UREN KF, KELLY DT: The value of exercise electrocardiography and exercise thallium-201 myocardial perfusion scanning in determinig the presence of single vessel coronary artery obstruction. *Aust N Z J Med* 10: 520, 1980
 8. BOTRINICK EH, TARADASH MR, SHAMES DM: Thallium-201 myocardial perfusion scintigraphy for clinical clarification of normal, abnormal and equivocal electrocardiographic stress tests. *Am J Cardiol* 41: 43, 1978
 9. VERANI MS, MARCUS ML, RAZZA KI: Sensitivity and specificity of thallium-201, perfusion scintigrams under exercise in the diagnosis of coronary artery disease. *J Nucl Med* 19: 773, 1978