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Precordial Isopotential Electrocardiographic Mapping and Its Clinical Use in Patients With Ischaemic Heart Disease

M. JANOTA, I. MÁLEK, V. STANĚK

Department of Cardiology, Institute for Clinical and Experimental Medicine, Prague

Summary

After ten years of experience, the authors present an overview of the possible clinical uses of precordial isopotential electrocardiographic mapping in patients with ischaemic heart disease. The resting Q wave and ST segment maps have most often been found useful in the early phases of myocardial infarction. They are a helpful tool for monitoring progression of the disease, the effect of drugs, or the therapeutic effect of fibrinolytic therapy, etc. R wave mapping provides an excellent opportunity for following up patients after orthotopic heart transplantation and monitoring cardiac rejection. Stress tests are usually performed under a workload; alternative loads may be mental, pharmacological, stimulation-induced or under hypoxaemic stress. To evaluate a test, resting values are compared with those obtained during exercise. It is mainly exercise ST segment maps which have proved to be most informative; their use in the chronic phase of ischaemic heart disease helps to make the diagnosis of coronary insufficiency more accurate. In clinical practice, stress tests are recommended mostly in the follow-up of drug therapy, monitoring of the therapeutic effect of cardiac surgery or coronary angioplasty.

Key words

Precordial ECG mapping – Clinical use – Ischaemic heart disease

Introduction

Various non-invasive methods have been developed and employed to make the diagnosis of myocardial ischaemia more accurate; these include electrocardiography, echocardiography and radionuclide methods in particular. The main method for examination of patients with ischaemic heart disease (IHD) is electrocardiography (ECG). The value of ECG has been enhanced by the advent of cardiac mapping, a method developed by Waller (1889), the clinical use of which was pioneered by Taccardi (1963). It is employed experimentally and has been introduced into clinical practice for the diagnosis and evaluation of the extent and localization of ischaemic lesions, for establishing the prognosis and for monitoring the effects of therapy. For the diagnosis of myocardial ischaemia, contemporary physicians often use isopotential maps determining the magnitude of cardiac voltage from a relatively large number of measurement sites (32, 56 or even more).

Precordial mapping of IHD patients at rest has been employed for a longer time (Maroko *et al.* 1977, Filipová and Cagáň 1990, Málek *et al.* 1988). In the past decade, precordial mapping has been extensively used for exercise testing (Fox *et al.* 1979, Miller *et al.* 1980, Mirvis 1980, Janota *et al.* 1985). While new techniques are being developed and optimal lead systems for precordial ECG monitoring are being sought (Lux *et al.* 1979, Filipová and Cagáň 1990), current systems of automatic evaluation are being improved and recording techniques are being refined.

For exercise mapping to gain more clinical acceptance, it is critical to improve the technique of ECG recording, to develop well-fixed multielectrodes, to produce fast operating microprocessors enabling automated evaluation, and systems allowing high-resolution and rapid visualization of the results.

We decided to summarize our experience and to offer our own perspectives of the possible clinical applications of precordial isopotential ECG mapping in IHD patients. The information will be presented in two parts, one devoted to precordial mapping at rest and the other to exercise mapping adopted in recent years.

Methods

Precordial isopotential maps are obtained using a CARDIOMAP-1 system devised and built in our department in 1981 (Lexa *et al.* 1981, Janota *et al.* 1985). The system is designed to record peak Q, R, S waves and the ST segment of the electrocardiogram by means of a microcomputer with microprocessors. The system comprises a multielectrode, an input controlling unit, a computer, a screen, a keyboard, and a printer making it possible to obtain hard copies of the monitored maps, to calculate the sums of Q, R, S as well as ST segment elevations and depressions, and the heart rate. The sums of Q, R, S waves are calculated as the sum of peak voltage amplitudes of these waves in all 56 thoracic leads, and given in millimeters. The sums of ST elevations and depressions express their deviation from the zero line 70 ms after the S wave peak (ST 70 ms). It is also possible to calculate the area of Q waves and ST segment elevations or depressions using this system. It produces hard copies of all monitored parameters and records selected electrocardiograms from all leads.

Examination procedure

Flexible 12x28 cm multielectrode is placed on the right medioclavicular line, from the fourth intercostal space to the left axillary line. The electrodes are made Ag-AgCl and make contact with the skin using a felt saline-filled roller. The electrodes are evenly spaced in columns 4 cm apart, and in rows at 2-cm intervals. The evaluated electrocardiograms are visualized in the screen of an alpha-numeric monitor in the form of isopotential maps and tables and are registered on a printer. Basic results of examinations at rest are expressed as mean values of repeated triple measurements with computer-aided evaluation.

Stress tests

In stress tests, data obtained from tests at rest and during exercise are always compared and, as a rule, the findings of a control group of subjects are compared with those obtained from IHD patients. The evaluation of individual examinations in a given subject is based on a comparison of examinations at rest performed before and after stress, or before and after medication.

Exercise testing

Exercise electromaps are obtained using an Elema ergometer in the sitting position with increments of 1 W/kg and 2 W/kg with a 3 min interval inbetween. Post-exercise recording continues until the patient has calmed down within several seconds, and is repeated up 2 or 4 min.

Cardiac pacing

Transoesophageal atrial stimulation is performed using a Vygon multilead catheter and a pacemaker which we developed, giving impulses of 10 μV and 15-20 mA current. One-minute ascending stimulation is employed until the onset of symptoms or for the period of 1:1 AV conduction.

Mental test

Mental stress testing consists of an arithmetic test involving subtraction of 7 from 100, as devised by Deanfield *et al.* (1984), and Stroop's colour test of coloured words with different meanings.

Hypoxaemic test

The hypoxaemic test is performed by 5 min inhalation of 10 % O_2 in 90 % N_2 with a flow of 10–15 l/min from an open circuit using a two-way valve via a tube and a small anaesthetic bag. The mixture is prepared in a gas bottle with a reduction valve.

Results

Resting isopotential Q wave maps are employed in acute myocardial infarction to monitor the course of the disease, the effect of treatment and to evaluate the prognosis. The first to use such a map were Maroko *et al.* (1977). Some current potential applications are summarized by Málek *et al.* (1988) who, on the basis of the development of sums of Q and the number of sites with the incidence of Q wave, sought to evaluate the course of changes due to myocardial necrosis while monitoring patients after myocardial infarction over a period of 12 months. A maximum of changes was found as early as three weeks with the sums decreased by 15 % whereas there were no further changes thereafter (Tab. 1).

The Q wave map makes it possible to identify regional lesions in more detail that can be done by conventional electrocardiograms. Moreover, it is possible to specify the extent of lesions and especially of necrosis of the proximal wall. Some lead systems also provide good records from the posterior wall (Lux *et al.* 1977, Filipová and Cagáň 1990).

The early phase of myocardial infarction and the effect of fibrinolytic therapy by means of precordial mapping was evaluated by Staněk *et al.* (1990). The changes of the Q wave were over within 12 hours although the onset of symptoms and the lesions in the maps persisted in the ensuing period. Complete healing was observed within 3 months. These authors considered the maps useful in monitoring the effects of fibrinolytic therapy. They monitored two groups of patients: the sums fell to lower values in subjects with a low initial Q wave than in those patients with high Q waves at the beginning of the study.

The subsequent course following successful coronary artery recanalization by fibrinolysis was monitored by Šochman *et al.* (1992). To evaluate their patients, they also used Q waves which tended to decline depending on the improved left ventricular function assessed by an increasing ejection fraction.

Table 1
Sums of Q (Σ Q) and the number of Q points (abnormal Q waves) (n Q) during 12 months after myocardial infarction. I – 3 weeks, II – 3 months, III – 6 months, IV – 12 months.

	I		II		III		IV	
	Σ Q	n Q	Σ Q	n Q	Σ Q	n Q	Σ Q	n Q
x	153.8	18.3	129.7	17.1	130.3	16.3	117.8	15.3
SD	88.5	8.1	76.7	8.1	89.3	8.7	77.5	7.9
p <			0.005	ns	0.005	0.01	0.005	0.001

ST segment maps at rest

ST segment maps obtained at rest are used exclusively in the early phase of myocardial infarction. ST segment elevations are considered as a manifestation of transient myocardial ischaemia. They attain a peak within 12 hours and persist up to 30 hours. These changes are reversible during the ensuing course. In the early phase of myocardial infarction, the resting maps of the ST segment can be used for monitoring the therapeutic effects, e.g. in fibrinolysis or in acute coronary angioplasty (Málek *et al.* 1988).

R wave mapping

Evaluation of isopotential R wave maps at rest has proved to be useful in special indications, i.e. in diagnosing of cardiac graft rejection. In a relatively large group of 45 patients after orthotopic heart transplantation in a long-term follow-up, who exhibited mild cardiac graft rejection, we have noted a significant decrease in R wave maps, and a reduction in the sums of R waves which gradually returned to the initially higher values after therapeutic intervention. The agreement between biopsy findings and data obtained from the maps was high: sensitivity of the examination was 89 % and the specificity 85 %. Similarly as Aleixo *et al.* (1988), we have adopted R wave monitoring as a technique for monitoring cardiac graft rejection (Janota *et al.* 1990b).

Exercise map testing

Electrocardiography is a routine method used in the diagnosis of coronary insufficiency enabling correct diagnosis in about 70 % of examinations. More accurate results can be obtained when using isopotential ECG mapping from the body surface by means of several thoracic leads in the precordium and their appropriate localization (Fox *et al.* 1979, Mirvis 1980, Miller *et al.* 1980, Janota *et al.* 1985). Various types of exercise maps have been developed which were obtained by ergometry and on a treadmill and the findings were compared at rest and during exercise, or immediately after its completion.

Ischaemic lesions can be well identified by isopotential ST segment maps. Evaluation makes it possible to monitor the sums of voltage denivelations from all monitored leads, the so-called sum of ST segment elevations or sum of ST segment depressions. Changes in the Q,R,S wave sums and other values did not prove to be helpful in evaluation of transient ischaemia. Exercise ST maps help to evaluate the extent of ischaemic lesions. The extent of lesions evaluated by the number of infarcted coronary arteries corresponds to the extent of lesions as shown in exercise ST maps (Janota *et al.* 1985, 1989).

Superior model of mapping systems make it possible to localize more accurately the lesions than the conventional electrocardiogram. Naturally, this ECG method also has its limitations. Localization of single artery lesions can be pinpointed rather than multiple arterial lesions. Results are modified by interindividual variability of the coronary bed, the degree of current development of collaterals, presence of the steal phenomenon, etc.

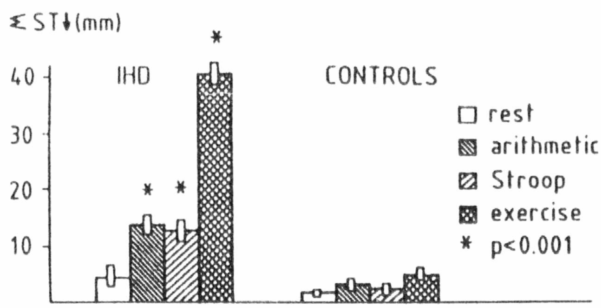

Fig. 1
Sums of ST depressions in mm (ΣST) in ischaemic heart disease (IHD) and in controls at rest, during the arithmetic test, Stroop's test and during exercise. Values are mean ± S.E.M. Asterisks denote significant differences from controls (p<0.001).

Mental test

When performing the arithmetic test and Stroop's test, we found manifestations of ischaemia in maps and significantly increased sums of ST depressions, although their degree was lower than that found during exercise. In IHD patients under mental stress the lesions were present in 35-45 % of the examinations. While the mental test cannot compete with exercise testing, it appears that it could be helpful in detecting silent ischaemia in some cases (Janota *et al.* 1990a) (Fig. 1).

Stimulation and pharmacological test

In the diagnosis of ischaemia evaluated by means of ECG methods as well as by electrocardiography and pharmacological tests (dipyridamole or dobutamine) play an increasingly important role. Mapping of responses to transoesophageal atrial stimulation was found to be especially useful, mainly on account of its easy reproducibility in subjects with limited mobility (Janota *et al.* 1990a).

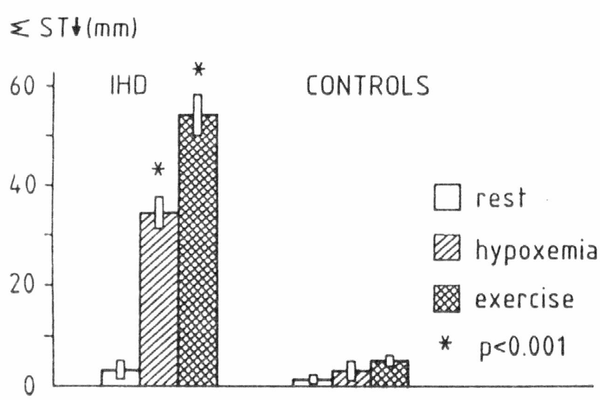

Fig. 2
Sums of ST depressions in mm (ΣST) in ischaemic heart disease (IHD) and in controls at rest during the hypoxaemic test and the exercise test. Values are mean ± S.E.M. Asterisks denote significant differences from controls ($p<0.001$).

Hypoxaemic test

Some time ago, the hypoxaemic test was widely used in electrocardiography. In the hypoxaemic test evaluated by mapping, we find changes similar to those obtained during exercise, the sums of ST depressions rise quantitatively less significantly than during exercise testing (Fig. 2).

Discussion

An important step to a wider acceptance of precordial mapping in clinical practice was to use resting precordial mapping in patients with ischaemic heart disease. Experiments and research projects evolved into more frequent clinical applications in patients with myocardial infarction in coronary care units. Resting ECG mapping is becoming an increasingly helpful follow-up of different methods of treatment. We were able to demonstrate this both when evaluating surgical management and coronary angioplasty (Janota *et al.* 1991b). It seems that monitoring of cardiac graft rejection using R wave mapping will be used in clinical practice (Janota *et al.* 1990b).

To make the diagnosis of myocardial ischaemia more accurate, exercise testing has become increasingly popular. Precordial exercise isopotential mapping of the ST segment is the principal examination technique employed in myocardial ischaemia and helps to quantify the extent of functional impairment. Exercise testing today does not only involve exercise testing as such but also stimulation, mental, hypoxaemic and especially pharmacological tests (dipyridamole, dobutamine, etc).

Our experience makes it imperative to monitor the sums of Q,R,S wave and ST segment elevations and/or depressions and to look out for the differences between sta.dard and abnormal findings.

Electromaps obtained from precordial mapping are an important adjucts of the clinical examination. The standardization of the evaluation is, however, still rather difficult. If precordial isopotential ECG mapping is to find a widespread acceptance, it is essential that inexpensive sophisticated automatic technology will be available.

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Reprint Requests

MUDr. M. Janota, M.D., Ph.D., Department of Cardiology, Institute for Clinical and Experimental Medicine, Vídeňská 800, 140 00 Prague 4, Czech Republic.