Q Wave Myocardial Infarction Analysed by Body Surface Potential Mapping

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Abstract

Body surface potential maps were recorded from 64 electrode positions in 19 normal subjects and 29 patients with either anterior or inferior myocardial infarction (MI). QRS, ST80, ST-T, Q and QST80 maps were generated for all patients and patterns were found corresponding to normal activity, inferior MI and anterior MI. Other variables were extracted related to ST voltage values and presence of pathological Q waves in order to analyse its correspondence with 12-lead electrocardiographic findings and with functional and anatomical measurements derived from magnetic resonance and echocardiography: perfusion, viability, ejection fraction and thickness.

Electrical information was found in body surface potential mapping measurements not detected by 12-lead ECG for MI patients. Wall thickess, perfusion and viability appeared to be related to Q wave presence and maintained ST elevation.

1. Introduction

Body Surface Potential Mapping (BSPM) is an advanced electrocardiographic technique aimed at estimating the global potential distribution by recording potentials at multiple sites on the thoracic surface.

Although this technique was developed a few decades ago, its present use is still restricted to research laboratories. There are still some reasons supporting its distance from clinical use. First, it is quite impractical to acquire a large amount of signals from the torso surface but mainly it has to be proven that BSPM represents a major diagnostic advantage.

In the past, different research groups applied BSPM in the study of some cardiac diseases with different rates of success [1,2,3]. In most of their studies some improvement in diagnosis was shown, but it didn't justify the application of such a laborious method.

Recently, special attention is being focused on the study of myocardial infarction making use of BSPM, showing promising results on the improvement of myocardial infarction detection by using specifical body surface maps [4,5,6].

The aim of our research is to evaluate BSPM adventages in the study of myocardial infarction. We study map patterns and the correspondence between BSPM findings and functional and anatomical measurements derived from magnetic resonance. With this objective we developed our own system to record BSPM signals and created specific software to analyse them. We chose Matlab 6.5 as programmig environment and developed an easy to use application with graphical interface functions, enabling inexperienced users to perform specifical analysis to BSPM recordings. Results of our research are discussed in this paper.

2. Materials and methods

2.1. Study population

We prospectively studied 48 subjects, 19 of whom were normal and 29 were patients with a first Q wave myocardial infarction. All patients and controls gave informed consent. The normal group consisted of 4 women and 15 men with no evidence of heart disease by history, physical examination and 12 lead electrocardiogram.

All patients included in the study were admited in the HCUV because of a first Q wave myocardial infarction. BSPM recordings were taken within the first week after recovery in 4 patients (14%) and within 6 months after recovery in 25 patients (86%). Myocardial infarction was diagnosed on the basis of typical chest pain lasting > 30 minutes, ST elevation > 0.1 mV presented in at least two leads from the 12 lead ECG, and an increase in troponin I >1 ng/ml. Patients were eligible for inclusion if they fulfilled the following inclusion criteria: 1) Stable clinical course without complications. 2) Q waves of ≥ 0.04 s duration and ≥ 25% of the amplitude of the R wave in depth in two or more contiguous leads. 3) Absence of any condition known to provoke ST segment alterations. 4) Absence of clinical history suggesting any prior heart disease. 5) Single-vessel disease and a patent (with a residual lesion <50%) infarct-related artery at the end of

0276–6547/04 $20.00 © 2004 IEEE

Computers in Cardiology 2004;31:725–728.

the cardiac catheterization performed before discharge. For all patients myocardial perfusion was assessed with angiographic blush, intracoronary myocardial contrast echocardiography and magnetic resonance (MR) and myocardial viability was quantified by means of magnetic resonance (transmural extent of necrosis). The patients group consisted of 28 men (96.5%) and 1 woman (3.5%). They were clasified into two groups: anterior myocardial infarction (AMI), present in 16 patients (55%) and inferior myocardial infarction (IMI), present in 13 patients (45%).

2.2. Body Surface Potential Mapping System Description

The system used to record electrocardiographic signals has been previosly described [6]. Briefly, it makes use of a commercial 64-lead acquisition system for biopotential measurements (Active One from Biosemi [7]) adapted to our purposes. In this system, all acquired potentials are referred to one electrode defined as the electrical reference. Electrocardiographic signals are sampled at 2048Hz with a quantization of 1μV/bit and stored on hard disk by means of a computer for its later processing.

Electrodes are distributed non-uniformly upon the chest: a set of 16 electrodes are placed uniformly in the back and the rest non-uniformly in the anterior side, with a highest density at positions overlaying the heart. Electrodes are mounted on an elastic vest designed by our group to be attached easily to the patient's body.

2.3. Signal Processing

Signal quality was monitored visually during the recording but some processing was needed in all cases. Electrical reference in acquisition is fixed on a surface point. This reference has to be changed before any measurement by software and all leads were referred to the average of all electrodes. All recordings were carefully edited to select a 10-second time interval with the lowest noise level. After this moment just this time interval was studied for each patient.

Base line fluctuations could be removed if necessary using a linear high pass filter (fc=1 Hz). High-frequency noise could also be reduced with an adjustable low-pass filter (usually fc=60 Hz, but changed according to the noise level present). When necessary, 50 Hz filtering was performed.

Electrode offset had to be completely removed for each lead since it introduces intolerable deviations in map display. It was calculated as the level in the PR segment and then arithmeticaly substracted to the original signal.

Finally, an averaged beat (PQRST) was computed for each lead from the 10 seconds studied in order to reduce beat to beat variability and noise

All leads were visually inspected in order to guarantee signal quality. If one lead did not present an acceptable noise level it was replaced by an averaged signal obtained from its neighbours. Patients with more than 3 useless leads were discarded.

Automatic detection of ECG waves was performed only for averaged beats. Qonset, QRS peak, J point, T peak and T offset were calculated for each lead. This detection is not critical as far as no time measurement is performed and is only used to define the averaged position of all waves. Anyway, every lead and its detected waves were edited individually.

As an important event in MI study, Q waves were detected for each lead and classified as pathological or not pathological according to the next criteria: length greater than 40ms, absolute peak value greater than 25% the absolute voltage at QRS peak and Q wave depth greater than the threshold defined for the lead where is presented. Q wave depth was measured as the integral value of the wave and thresholds were calculated from maximum depth values present at each lead for normal subjects. With these thresholds it is possible to distinguish Q waves resulting from normal activity (present in inferior and right lateral leads with different normal depths) between Q waves resulting from pathological activity (as far as they are present in depth and/or location which differs from that from normal subjects). Q wave detection and classification were manually edited to assure good performance.

2.4. Map display

Basically, four types of potential maps can be displayed with our software:

Isopotential maps: voltage distributions on the torso surface at one time instant are shown. In this group, we studied potential distributions at different time instants during ST segment: J point, ST60 (60 ms after J point) and ST80 (80 ms after J point).

Isointegral maps: averaged voltage distribution during a fixed time interval is shown in this kind of map. With these maps we studied the global potential distribution in QRS, ST and ST-T intervals.

Wave-integral maps: integral values of present waves (measured in V/s) are displayed. They differ from isointegral maps in the time interval, which is not fixed and depens on the wave duration for each lead. Leads without the studied wave will present zero values. In this group of maps we included Q-wave integral maps where depth and distribution of Q waves are shown.

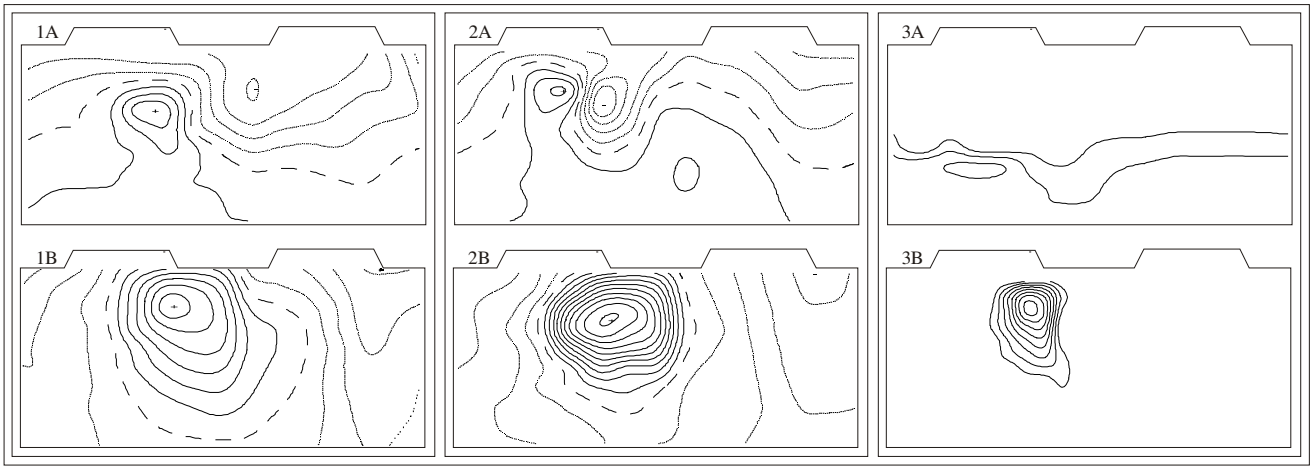

Figure 1.1: ST80 maps of two MI patients. The front of the subject is displayed left, the back right. Potential values are indicated with isopotential lines in 0.025 mV increments. Zero line is represented by a dashed line and negative values by dotted lines. A) IMI. B) AMI. Figure 1.2: ST-T integral maps. Isopotencial lines drawn in 0.025 mV increments. A) normal. B) AMI presenting inverted T waves. Figure 1.3: Q integral maps of two MI patients. Lines join points with same Q depth in 5 V/s increments. A) IMI. B) AMI.

Comparative maps: the joining of two different events is presented in this kind of map. We evaluated the simultaneous appearance of pathological Q waves and ST elevation in one lead.

All these maps could be presented in two different formats: 3D and rectangular plots. In 3D plots potentials are drawn in different colors on a modeled torso surface. In rectangular plots potentials are represented in a plane as an unrolled cylinder modelling the torso surface.

2.5. Data evaluated

From signal analysis of all patients we extracted some variables: nQ (number of pathological Q waves present in surface ECG), supQ (percentage of total torso surface that presents pathological Q waves), nST80 (number of leads showing voltage levels ≥ 0.1mV 80 ms after J point), supST80 (percentage of total torso surface with a voltage levels ≥ 0.1mV at 80 ms after J point), nQST (number of leads with both pathological Q waves and ST elevation) and supQST (percentage of total torso surface that presents both pathological Q waves and ST elevation).

By means of intracoronary myocardial contrast echocardiography with injection of Levovist (7 ± 2 days after BSPM) we measured perfusion (P) in a 0-1 scale. With cardiac magnetic resonance (7 ± 2 days after BSPM) we obtained: ejection fraction (EF: %), thickness (Th: mm) and viability (V: % of late enhancement after gadolinium administration).

3. Results and discussion

3.1. Maps

ST60, ST80 maps: in these maps three different patterns were observed, according to three different cases: AMI, IMI and ST recovery (present in patients with old MI).

IMI pattern (see fig.1.1.A) was present in 2 patients (100% of patients with recent IMI; 7.5 ± 2.5 days) minimum ST values are in the superior zone of the chest and positive values are present in the inferior zone. AMI pattern (see fig1.1.B) was present in 6 patients (86% in recent AMIs up to three months) showing a maximum in the midsternal region above V_2 and V_3 (≥ 0.15 mV). In recovery maps (found in 100% of normal subjects) positive values are present in anterior region, as in AMIs, but below V_2. Old MI patients (more than three months, 21 patients, 72%) could not be clearly classified in any of the groups.

ST-T maps: repolarization abnormalities, as presence and extension of inverted T waves can be observed in these maps (6 patients, 50% of recent MI) with negative zones over the anterior torso (see fig. 1.2).

Q-wave integral maps: we found two main patterns of Q-wave integral maps, corresponding to AMIs and IMIs. All patients could be included in one of these groups, according to their clasification into AMI or IMI.

IMI pattern (see fig. 1.3.A) shows Q waves on the inferior zone of the torso, with a higher depth on the right side. AMI pattern (see fig. 1.3.B) shows a great negativity on the anterior side of the torso, with different depths and extension depending on the patient.

Q-ST comparative maps: 12 patients (41%) showed leads with simultaneous presence of pathological Q waves and ST elevation. All non-zero maps presented the same pattern with coincident values on the anterior zone.

3.2. Data evaluation

Electrocardiographic findings in BSPM recordings

were compared with 12 lead ECGs. With 12 leads 7 patients (24%) did not show pathological Q waves whereas with BSPM only 1 (3%) had no Qs. All cases without Qs in 12-lead ECG were IMI. Studying ST elevation similar results were found, 15 patients (52%) presented ST elevation in BSPM recordings but no elevation in 12-lead ECG.

Table 1: Electrocardiographic findings:12-lead vs BSPM

Number of patients	12- ECG	BSPM
Pathological Qs (total)	21 (72%)	28 (97%)
AMI	15 (94%)	15 (94%)
IMI	6 (46%)	13 (100%)
ST elevation (total)	11 (38%)	26 (90%)
AMI	11 (69%)	14 (88%)
IMI	0 (0%)	12 (92%)

Comparing MR variables versus BSPM we found that patients with nQ>11 (45%) had similar EF and V than those with nQ≤11 but a thinner Th.

Table 2: RM vs nQ in BSPM

	nQ>11	nQ<11	p
EF	54±12	50±14	ns
V	47±28	44±26	ns
Th	7.8±1.6	9.6±2.4	0.03

Patients with nQST>0 (55%) had a more depressed EF, more myocardium without V and less P than those with nQST=0.

Table 3: Image vs nQST in BSPM

	nQST>0	nQST<0	p
EF	45±12	57±11	0.009
V	57±20	35±29	0.04
P	0.68±0.23	0.95±0.25	0.01

4. Conclusion

In a stable phase after MI, BSPM detects Q waves and ST elevation unobserved with convencional ECG, especially in IMIs. Spatial representation of Q waves enables 97% MIs classification into AMI or IMI with independence of its antiquity by comparing resulting maps with patterns found. Number and extent of Q waves were compared to other variables from RM and ecocardiography, and it was found that they are related with a thinner wall but poorly with the systolic function.

ST elevation by itself provides poor diagnostic information in old MIs, but the extent of abnormal Q waves with maintained ST elevation indicates a more affected left ventricular performance and a more damaged microvasculature.

Results from this study show that there is electrical information on the chest surface undetected by 12-lead ECG as Q waves and presence of ST elevation in myocardial infarction. This loss of information is specially important in inferior MIs as the chest zone which presents these injuries is usually not explored. Also, electrical information registrered from torso surface can be related with the severity of the myocardial damage although the amount of cases studied is not large enough to assure it.

Acknowledgements

This work was supported by TIC2002-009 project. The authors wish to thank the HCUV staff, and specially to Mauricio Pellicer for his invaluable help.

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