Clinical application of body surface potential mapping in ischemic heart disease

Doctoral theses

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Budapest

2011.

INTRODUCTION

In Hungary - like in other countries of Europe and the developed world- cardiovascular disease (54%) is the leading cause of morbidity and mortality, ahead of cancerous diseases (27%). In Hungary, taking into consideration the entire population, 1057 in every one hundred thousand people have circulation disorders, and 488 have ischemic heart disease. Two thirds of all deaths are caused by atherosclerosis with coronary-artery stenosis in the background, meaning practically that every forth death is caused by ischemic heart disease (IHD). IHD will be the leading mortality factor by 2020, including third world countries as well.

Angina pectoris is the most frequent symptom of IHD. The incidence of IHD increases with age and is more frequent among men (2-5% between 45-55 y, and 10-20% between 65-75 y). This means that in Europe there are 20-40,000 patients per 1 million people. In Hungary – knowing the public health data and risk factors– we are able to calculate that there are 400,000 patients with angina. The disease frequently causes disability and results in significant health care costs. Atherosclerosis develops slowly and without symptoms in the

background, later causing rapid, unexpected death from acute coronary syndrome and stroke.

Before any physical signs of developing ischemia are detectable, it is measurable on the electrical field. The investigation of electrical signals generated by the heart began more than a hundred years ago. The fine spatial and temporal distribution detectable on the surface of the body has fundamental significance in the diagnostics of electrical properties of heart muscle. In clinical practice, we have used the traditional 12-lead electrocardiogram (ECG) since the beginning of the last century. Body surface mapping systems were a huge advance when they appeared. Body surface potential mapping (BSPM) allows us to more precisely evaluate electrical events of the heart muscle due to its better spatial distribution. This is a proven clinical advantage over ECG. Myocardial ischemia often manifests in minor, slightly detectable electrical potential loss, which can only be visualized by BSPM with the help of more sophisticated maps such as isopotential maps. In the course of research, our team investigated the possibilities of BSPM in the IHD population. My project focused specifically on coronary artery disease behind IHD.

AIMS

1. My aim was to prove that BSPM is a feasible method in the diagnostics of ischemic heart disease by detecting and localizing potential changes on the body's surface which are undetectable by ECG.
2. a) My aim was to prove that BSPM is a feasible method to detect and localize coronary artery lesions.

   b) I aimed to estimate the role of BSPM in clinical decision making by identifying culprit lesions in the case of multiplex coronary artery lesions.
3. My aim was to prove the claim that BSPM has the ability to detect coronary artery status in different manifestations of ischemic heart disease.
4. My aim was to prove that BSPM is a suitable method to evaluate electrical potential losses after successful percutan coronary intervention (PCI).

METHODS

Possible applications of BSPM in diagnostics of ischemic heart disease

Our investigations were executed with 63 chest lead mounted according to Montreal-system and using ProCardio 5.0 hardware. Analog signs were digitalized after optimizing the sign/noise level and generating isopotential maps with the help of ProCardio 5.3 software. During the analysis of BSPM maps, we used some qualitative characteristics differing from normal population and some quantitative (Timeshift, Max/Min ratio) characteristics. "Timeshift," one of the methods we used, measures the time interval (beginning from start of QRS) between the maximum positive and minimum negative potential values. The other quantitative method was the 'Max/Min ratio,' which is the ratio of maximum and minimum potential values on the body's surface during a heart cycle. Each region was identified according to Selvester predefined left heart ventricle segments.

As gold standard all of the patients underwent coronary arteriography.

After patient selection, 228 patient were investigated (164 male, 31-86 y, mean 61.6 ± 9,5 y) continuously between 01.06.1997 – 06.30.2005.

The patients were divided into subgroups according to clinical signs as follows: the patient a) experienced first time angina; b) already had angina; c) had unstable angina (UA) before; d) had non-ST elevation myocardial infarction (NSTEMI) in their case history.

During the statistical analysis, we used multiple logistical regression-analysis, receiver operating characteristics (ROC) curve analysis, odds ratio (OR), and likelihood ratio beyond traditional evaluation methods.

Estimating PCI efficiency in IHD patients

Our research was expanded to analyzing IHD patients after PCI. The quantitative parameters, already detailed in the "Methods" part of this thesis, served as the background of our investigations. We tried to estimate the efficiency of PCI during depolarization with the help of BSPM isopotential map analysis. Ninety-two IHD patients underwent coronaro-angiography, 70 of which (46 male, 40-86 y, mean 59 y) were PCI as well (in order LAD: 38, RCA: 17, CX: 15). Twenty-

two patients had no PCI (14 male, 33-76 y, mean: 60). The results before and after PCI were matched and analyzed statistically using the “paired t-test”.

RESULTS

Possible applications of BSPM in diagnostics of ischemic heart disease

First we investigated the potential losses detected by BSPM using *qualitative* and *quantitative* parameters separately.

Significant differences between *qualitative* parameters developed most often in patients with NSTEMI (88%) or earlier unstable angina (49%). The departures appeared less frequently in patients with ’only’ angina before (15% without case history of NSTEMI, and UA) and in patients with first time angina (9%). BSPM changes were observed in the healthy control population, too (8%).

With the *quantitative* parameters (Max/Min ratio and Timeshift), we often observed changes in both the NSTEMI (91%) and UA (84%) groups. The occurrence of quantitative

parameter changes was lower in the case of patients with earlier angina (80%) and first chest pain (61%).

Investigating 228 patients who experienced chest pain but had no actual ischemic ECG changes, we found significant coronary artery lesions in 215. Studying the patients with proven coronary artery lesions, the combined (qualitative, quantitative) BSPM parameters showed alterations in 193 cases (91% sensitivity) and gave correct indication of coronaro-angiography. In 13 patients with invasively examined negative results, the BSPM showed no changes in 10 cases (specificity 77%).

The likelihood ratio showed strong positive correlation in case of patients with earlier ischemic events (NSTEMI, UA, earlier anginas) and showed no correlation in patients with first angina.

We used the results of multiple logistic regression (85% likelihood threshold – modeled prevalence) in order to localize significant coronary artery lesions. The highest sensitivity we observed was in the case of left circumflex artery (CX) and right coronary artery (RCA) / posterior descendent artery (PDA) and left anterior descendent artery (LAD) distal lesions, but the specificity was low.

We obtained the highest specificity, with lower sensitivity, in the cases of left main (LM) and LAD proximal lesions.

The combination of highest positive and negative predictive value we experienced was in the case of LM, LAD proximal and RCA/PDA lesions.

The best diagnostic values in detecting changes on body surface potential maps appeared in the cases of RCA/PDA and LAD proximal lesions, where the area under the ROC curve was the largest; i.e. by 90% specificity the sensitivity was 78% in the case of RCA/PDA and 62% of LAD proximal lesions.

The lowest diagnostic value arose in the group consisting of CX first marginal and/or LAD first diagonal (by 90% specificity 19% sensitivity).

Analyzing OR, we came to the conclusion that the likelihood ratio is higher in the groups with coronary lesions where more than one region showed potential loss. The most often observed regions with potential losses were inferobasal, inferoseptal-middle, and anteroseptal-middle that marked coronary lesions with high likelihood ratio (patients with RCA/PDA, LAD distal stenosis).

The prediction of coronary artery lesions was most successful in the NSTEMI and UA groups. In these groups, we

obtained significant results in the case of RCA lesions, where using 90% possibility threshold the positive and negative odds ratio (OR) was 28.4 and 0.26, respectively.

In the investigated population (228), the coronaro-angiography showed two or more vessel diseases for 172 patients (75%). Among these patients, we detected potential losses in 79 cases affecting more than one region. Using Fisher discriminant analysis, we showed that two or more vessel diseases were significantly more frequent in multiple potential loss cases than in one-vessel disease patients.

Estimating PCI efficiency in IHD patients

According to our results, we observed an increase in the Max/Min ratio after successful LAD PCI (+28±31%, $p<0,01$), in contrast to RCA PCI where we found a decrease (-32±20%, $p<0,01$). There was no significant change in the case of CX PCI (10±22%) or absence of intervention (+3±11%).

CONCLUSIONS

1. I showed that body surface potential mapping (BSPM) is utilizable in the diagnosis of ischemic heart disease by detecting electrical potential losses. It's main advantage is its substantially higher spatial resolution.
   a. I demonstrated that BSPM is a feasible method to detect the existence of potential losses non-traceable by traditional ECG; this is of importance in clinical practice in case of patients with chest pain. It helps to differentiate the cardial and extracardial complaints in the case of normal 12-lead ECG findings.
   b. I verified that BSPM is able to localize electrical potential losses; the BSPM adequately separated the ischemic regions. Improving earlier results, we also differentiated the BSPM signs of antero- and infero-septal regions using analysis of qualitative and quantitative parameters.
2. I showed that BSPM is able to predict coronary artery status in ischemic heart disease.

a. I demonstrated that BSPM is of good diagnostic value to detect the existence of vascular lesions. We predicted coronary artery lesions with high likelihood ratio in the case of patients with earlier non-ST elevation myocardial infarction and unstable angina.
b. I verified that BSPM is a feasible method to localize coronary lesions in difference cases. I reached the highest sensitivity in the cases of CX, RCA/PDA, and LAD distal lesions, but the specificity values were lower. The highest specificity appeared in the cases of LM, LAD proximal lesions, where the sensitivity was lower.
c. I demonstrated that BSPM is able to predict the culprit lesion. Multiple logistic regression analysis showed definitively strong statistical results in cases of LM, LAD proximal, and RCA/PDA lesions. This method helped in therapeutical decision making on numerous multiplex coronary lesion cases that we observed (75% of all cases); in the cases of LM and LAD proximal lesions, coronary-aorto-bypass graft

could be indicated vs. percutan coronary intervention.

3. I showed that BSPM has different diagnostic values in different clinical appearances of ischemic heart disease. Ischemic effects occurred once (e.g. first angina) does not inevitably cause alterations in depolarization (that is why it is not applicable to screening investigations). After recurrent ischemic events (recurring angina, unstable angina, non-ST elevation myocardial infarction - because of greater cell necrosis) the BSPM predicts the coronary lesions well.
4. I showed that BSPM is a proper method to estimate electrical potential changes on the body's surface after successful percutan coronary intervention (PCI) in patients with ischemic heart disease. By follow up investigations, we could assess the efficacy of PCI with the help of electrical potential changes of different heart regions in the cases of already known ischemic heart disease. One of the qualitative parameters - the Max/Min ratio – showed significant changes in certain situation. In the case of ischemic anterior regions, the Max/Min

ratio showed significant increase after successful LAD PCI. On the other hand, in the case of ischemic inferior regions, it showed significant decrease after successful RCA PCI.

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