body surface potential mapping,
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OPTIMAL LEADS SELECTION FOR ISCHEMIA DIAGNOSIS.

Abstract: This study aimed to identify the optimal leads locations in body surface potential mapping (BSPM) to detect acute ischemia, e.g. myocardial infarction. *Methods:* We studied 16 healthy controls and 12 myocardial infarction patients. The capability of a recording location to separate the groups was quantified by Discrimination Index (DI). It was calculated by subtracting the mean signal amplitude of the normal group from that of the patient group during the STT segment and dividing the resulting amplitude difference by the corresponding standard deviation within all subjects. *Results:* Locations of optimal recording sites are mostly on the precordial area and some points are scattered on the right back or left low chest. *Conclusion:* The BSPM lead locations for effective detection of myocardial infarction by evaluation of the ST segment as well as the T-wave were proposed. These locations are mostly outside the conventional 12-lead ECG recording sites.

1. INTRODUCTION

Standard 12 lead ECG recording is a widely used method to diagnose ischemic heart disease and its acute phase – myocardial infarction. Despite undeniable importance, the aforementioned method does not always allow to get complete information about electrical activity of the cardiac muscle. The usage of the increased number of ECG leads significantly extends this knowledge facilitating diagnosis of different cardiac diseases [1-4]. Unfortunately, multi-lead ECG systems are too cumbersome to be used in clinical conditions. Therefore finding the best leads placement which capture the most ECG signal energy is of great importance. Many works in that direction have been done during last decades e.g. [5-11].

There are two different trends in literature of optimizing number of ECG leads and its locations on the surface of the body. One of them focuses on finding the smallest number of leads, which allow for the best approximation of ECG potentials distribution on the surface of the body, received from system with large (more than 100) number of leads. This trend is represented mainly by Barr [5] and Lux [6,7].

The other trend of seeking optimal number of ECG leads and its best spatial locaton is connected with the diagnosis of particular cardiac disease. The representative of this trend is first of all Kornreich [8-11], who searches minimal number and optimal leads location allowing to increase sensitivity and specificity of diagnostic methods using chosen leads subsets.

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2. MATERIAL AND METHODS

The preliminary analysis of HR-ECG in the repolarization period was carried out on the set of data of 16 normal subjects and 12 post-infarction patients. The examination was carried out in the electrically shielded room using the high-resolution ECG measurement system.

The system consists of 64 low noise amplifiers with 16-bit A/D converters (BIOSEMI, the Netherlands). Digital signals sampled with frequency of 4096 Hz were transformed to the serial optical format and then were transferred to the computer via an optical fiber. The data acquisition was controlled by the LabView measurement software. To improve the signal-to-noise ratio the cross-correlation averaging and filtering methods were applied to 64 signals obtained from the lead position on the torso according to the University of Amsterdam lead system. The positions of leads are based on two 32 leads subsets selected by Lux [6-7] from 192 ECG leads by sequence selection algorithm [6] (Fig. 1).

In BSPM data baseline drift was eliminated with the use of the high-pass filter (f=0.33Hz) and the sampling frequency was decreased to 1 kHz (decimation filter). To obtain averaged ECG signals the cross-correlation function was calculated between manually chosen pattern of QRS complex and the whole signal. For alignment and averaging beats with correlation coefficient higher than 0.98 were chosen. Additionally, beats with higher values of noise were eliminated.

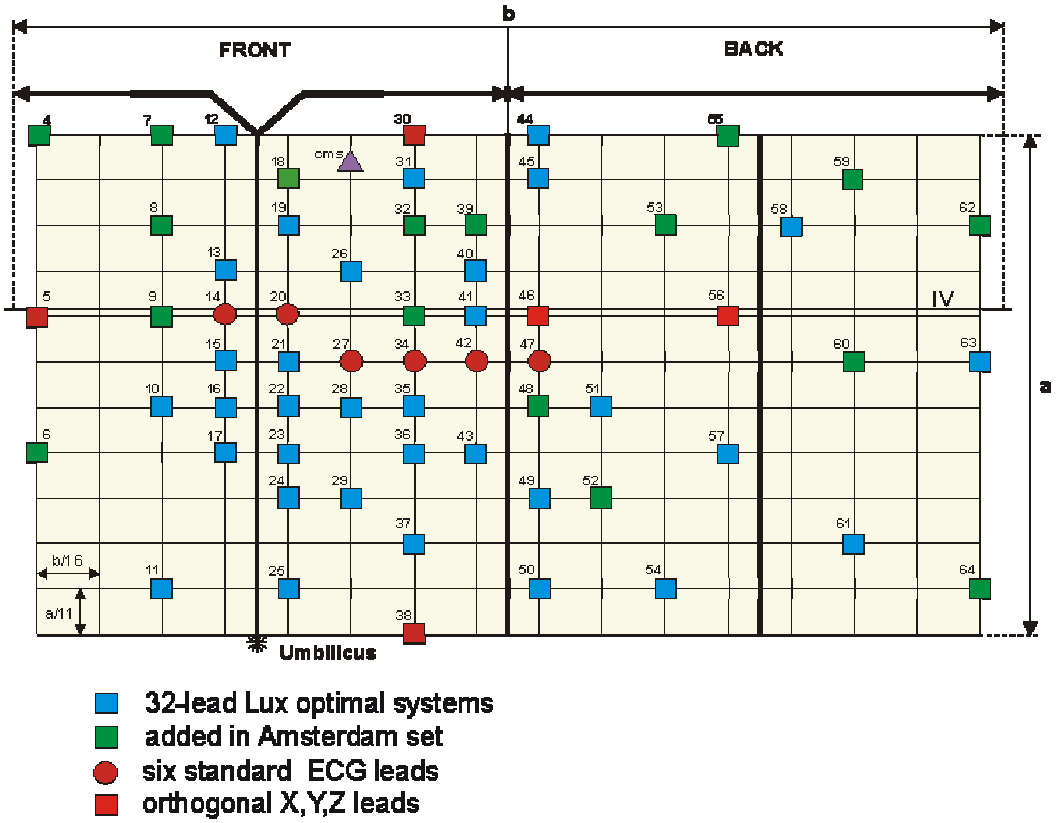

Fig. 1 The 61 lead system used in the analysis.

3. ANALYSIS

To find the best location of 12 and 16 leads form all 61 leads to distinguish the control group and the group of patients after myocardial infarction, the parameter called “Discriminant Index” (*DI*) proposed by Kornreich [8] was used. *DI* parameter was calculated for every time instant and in every ECG lead for STT segment.

STT intervals were normalized in both groups to 200 samples, and then partially integrated i.e. every 10 samples were integrated, so 20 segments were received. Then the mean STT voltage in each group, and in each electrode was calculated:

$$\overline{V\_STT}_{i,t} = \frac{\sum_{i=1}^{k} V\_STT_{k,i,t}}{k}, \qquad (1)$$

$$k \in (1,...N) \vee k \in (1...S)\,,\ i \in (1,...64)\,,\ t \in (1,...T_{STT})\,,$$

where *V_STT* is the potential V genereted during repolarization phase in time instant *t*, in lead *i*, in examined person *k* (Fig 2).

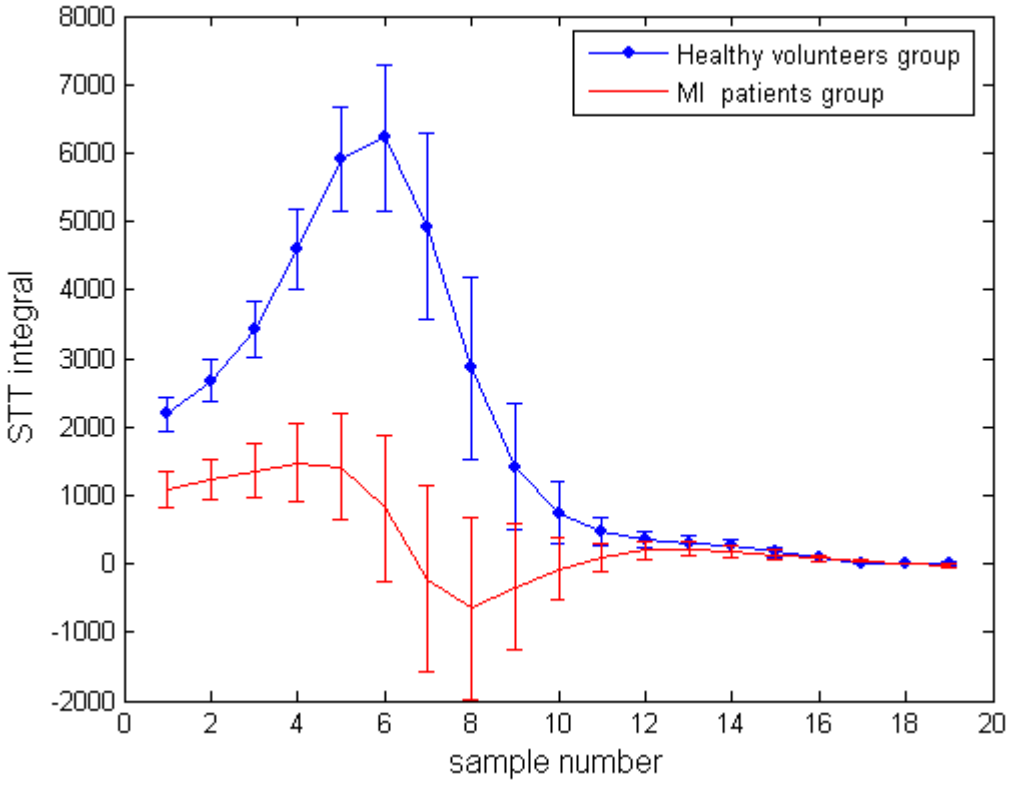

Fig. 2 $\overline{V\_STT}_{i,t}$ and standard deviations in lead number 20.

Then the mean potentials $\overline{V\_STT}_{i,t}$ of normal group were subtracted from MI group mean voltage for each time instant and each electrode. Sequential discriminant maps for each pairwise

comparison were obtained by further dividing each resulting difference by the corresponding composite standard deviation computed from the pooled groups:

$$DI_{i,t} = \frac{\overline{V\_STT}^{MI}_{i,t} - \overline{V\_STT}^{N}_{i,t}}{std\_STT_{i,t}}, \tag{2}$$

where $std\_STT_{i,t}$ for small groups is defined as follows:

$$std\_STT_{i,t} = \sqrt{\frac{(N-1)\cdot \mathrm{var}\_STT^{N}_{i,t} + (S-1)\cdot \mathrm{var}\_STT^{S}_{i,t}}{N-S-2}} \tag{3}$$

Thus the values achieved were strictly proportional to t test statistics and provided information on the capability for each measurement at each electrode site and at each instant to separate MI patients from the normal group.

The values of DI parameter calculated for lead 20 are presented in Fig. 3:

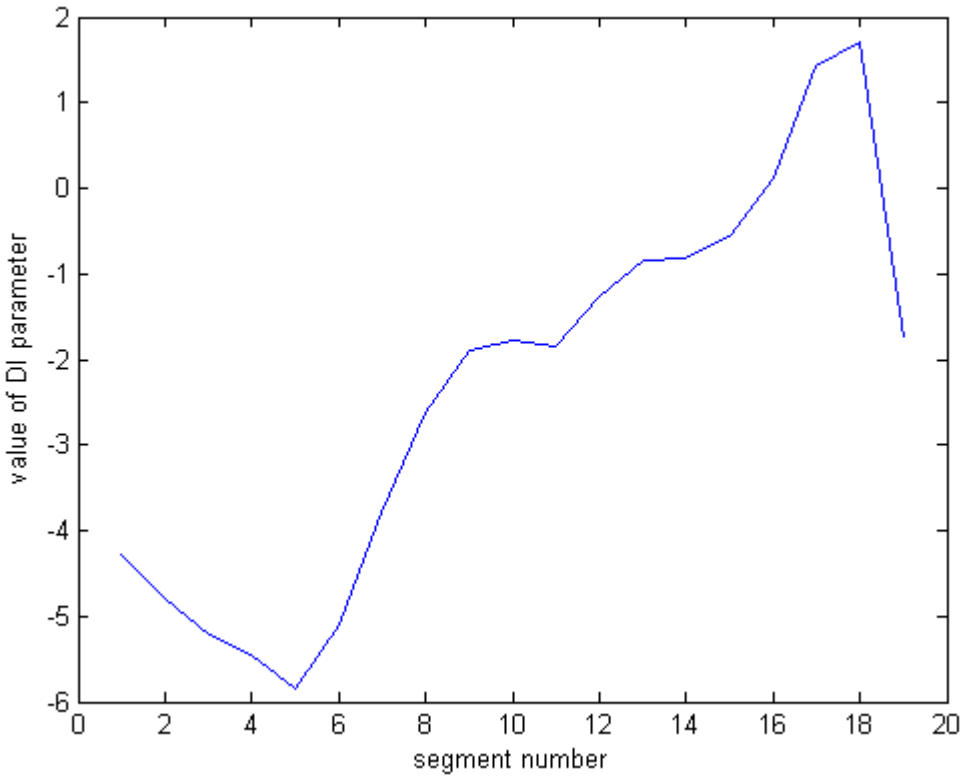

Fig. 3 Values of DI parameter as a function of each segment of STT interval in lead number 20.

4. RESULTS

During preliminary analyses of DI parameter calculated in 61 surface leads and 3 limb leads, sequentially, 12 and 16 lead sets having maximal value of DI parameter were selected, and are presented in figure 4. The four lead sets were chosen – 12 and 16 lead sets for surface of the whole thorax and 12 and 16 lead sets for chest only.

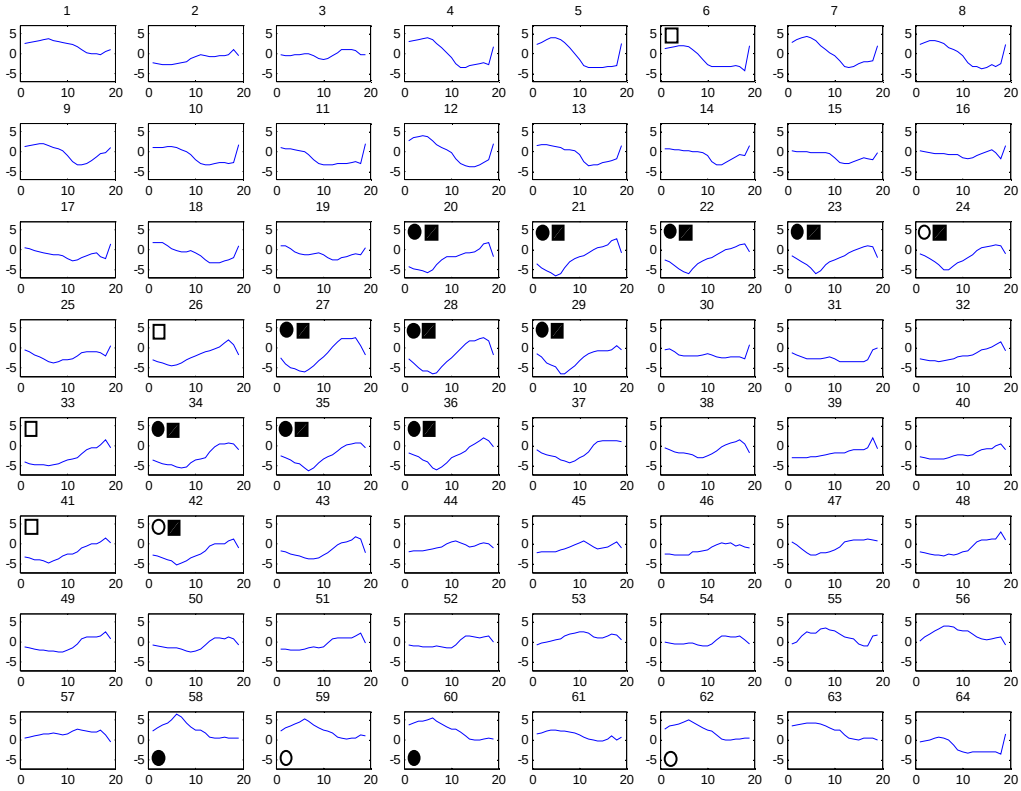

Fig. 4 Values of DI parameter in all leads. Filled circle – first 12 leads chosen for best location around the thorax, unfilled circle– added 4 leads to create 16 optimal lead subset; filled squares– first 12 leads on the chest, unfilled squares – added 4 leads to create 16 optimal lead subset on the chest.

According to results from Barr's work [5] most leads are situated in the precordial area. Some leads are placed in more scattered points e.g. on the right back or left low chest.

The following conclusion can be drawn: (1) optimal leads for MI (acute CAD) diagnosis are most often located outside the regions sampled by the standard ECG leads, (2) the problem of optimal leads selection has not unique solution. It strongly depends on examined cardiac disease, (3) further analysis is required especially with larger (statistically significant) number of patients suffered from coronary artery disease (CAD).

5. BIBLIOGRAPHY

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