Optimal Leads Selection for Repolarization Phase Analysis

M. Fereniec, M. Kania, R. Maniewski

Institute of Biocybernetics and Biomedical Engineering
Ks. Trojdena 4, 02-109 Warsaw, Poland
Email: malgosia@ibib.waw.pl

Abstract: *The study aimed to identify 12 and 16 optimal recording sites in body surface potential mapping (BSPM) to assess repolarization phase differences between healthy volunteers and myocardial infarction groups. The Discriminant Index and Sequential Selection Algorithm were used to study averaged ST-T waveform in 61 surface leads. Two methods of selection of optimal recording sites gave two different lead sets. For diagnosis purpose leads selected by Discriminant Index value were better, for approximation of information content the Sequential Selection Algorithm allowed for selection better recording sites.*
Keywords: BSPM, repolarization phase, optimal selection

1. Introduction

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 and placement of leads, which allow for the best approximation of ECG potentials distribution on the surface of the body received from systems with large amount of leads. This trend is represented mainly by Barr [1] and Lux [2]. The other trend of seeking optimal number of ECG leads and its best spatial location is connected with the diagnosis of particular cardiac disease. The representative of this trend is, first of all, Kornreich [3-5], who in his works searched minimal number and optimal leads locations allowing to increase sensitivity and specificity of diagnostic methods using chosen leads subsets. In this paper both techniques were applied to select optimal 12 and 16 lead sets to find lead subset with maximum information content or lead subset best for diagnostic purpose.

2. Subject 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 were sampled with frequency of 4096 Hz were. 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. 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, which correlation coefficient was higher than 0.98, were chosen. Additionally, beats with higher values of noise were eliminated.

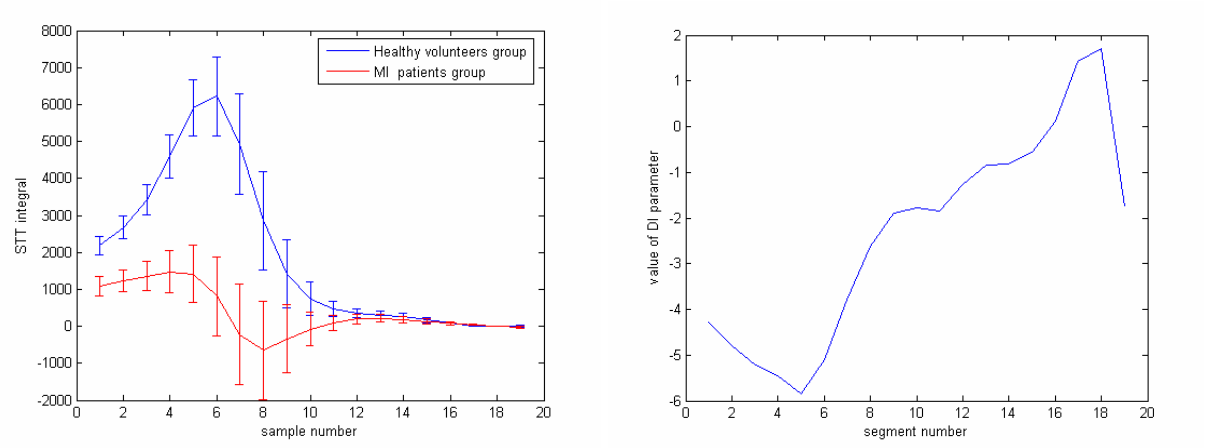
To find the best location of 12 and 16 leads from among 61 lead system to distinguish the control group and the group of patients after myocardial infarction, the parameter called "Discriminant Index" (DI) proposed by Kornreich [6] was used. DI parameter was calculated

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, in each electrode was calculated:

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

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

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



A B

Fig.2 A $\overline{V\_STT}_{i,t}$ and standard deviations in lead number 20, B - Values of DI parameter as a function of each segment of STT interval in lead 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

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

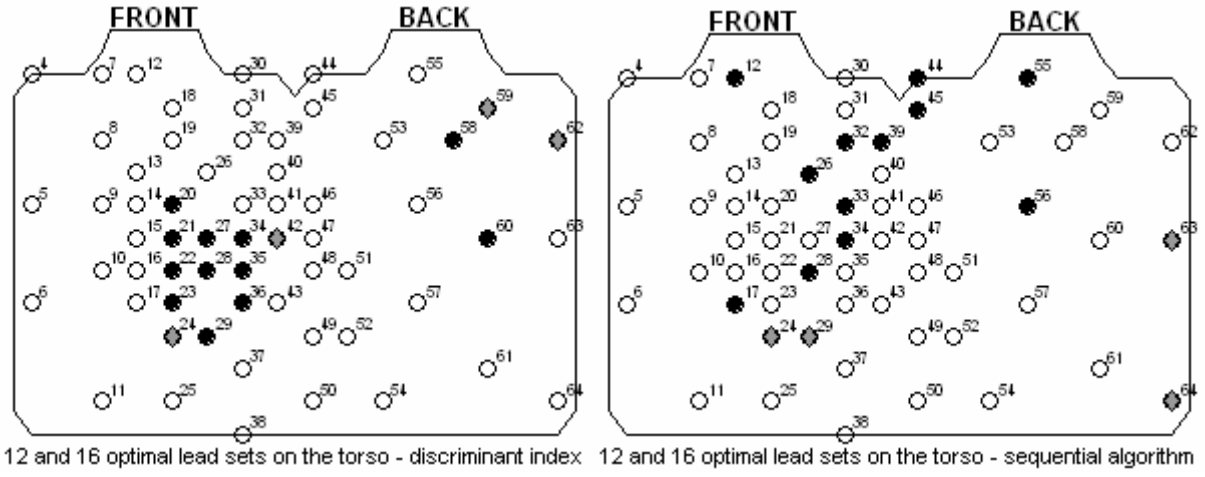
Thus the values achieved were strictly proportional to t test statistics and provided information on the capability for each measurement at each electrode site and at each instant

to separate MI patients from the normal group. The values of DI parameter calculated for exemplary lead 20 are presented in Fig. 2B.

The Sequential Selection Algorithm proposed by Lux in [2] was applied to find best 12 and 16 lead subsets. The algorithm is based on covariance matrix of ST-T waveform potentials. The recording site that had highest correlated power ("information content") with all other was selected at each step.

3. Results

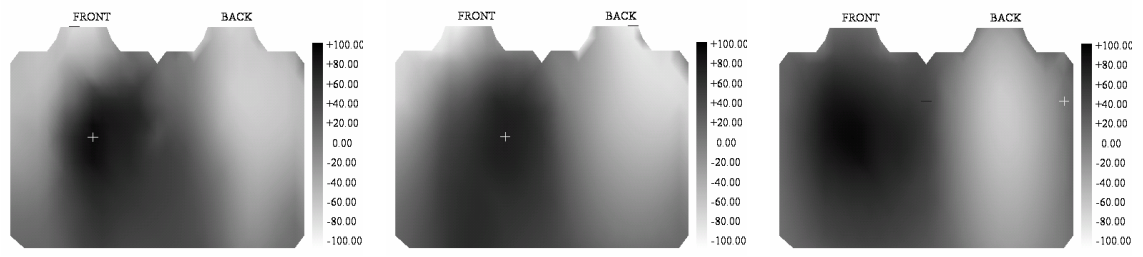
Below the 12 and 16 optimally selected recording sites are shown (Fig 3). Lead set selected using Discriminant Index includes 4 precordial leads from standard ECG set. Lead set selected using Sequential Selection Algorithm are more scattered around the torso.



A B

Fig 3. Optimally selected lead sets: A –using Discriminant Index; B – using Sequential Selection algorithm In black 12 optimal lead sets are shown , in grey 4 additional leads are shown.

The correlation coefficients between reconstructed STT integral map from lead set selected by sequential algorithm and the original map calculated from 61 leads are higher than correlation coefficients for lead set selected by Discriminant Index. Exemplary maps of mean map of STT integral averaged in healthy control group.



A B C

Fig 4. Mean map of STT integral averaged in healthy control group. A – map from 61 leads B – map from 12 leads using Sequential Selection algorithm (cc=0.96), C – map from 12 leads selected using Disriminant Index (cc=0.71).

4. Discussion

Optimal selection of lead subsets has not unique solution. Two methods presented in the study has given different lead sets, each one is optimal according to its method assumption. The most significant leads in Discriminant Index parameter are located in left, low precordial area, and optimal leads selected by sequential algorithm are scattered around the torso, with most leads on the chest. For the diagnostic, discrimination purpose the lead set selected by Discriminant Index (including 4 of 6 precordial standard ECG leads) is better, but in the same time it is worse for gaining the maximum information content. This would suggest that for the diagnosis of myocardial infarction or acute myocardial ischemia, based on ST-T waveforms, not the whole information content need to be used. Further analysis on larger database is required.

6. References

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