

Assessment of Number of Lesions from Integral Body Surface Potential Maps

M. Teplan, J. Švehlíková, M. Tyšler

Institute of Measurement Science, Slovak Academy of Sciences, Bratislava, Slovakia

Email: michal.teplan@savba.sk

Abstract. *In this simulation study various characteristics of difference STT integral body surface potential maps (DI BSPMs) were used to discriminate cases with single and double modelled lesions with changed repolarization. One or two lesions in different positions in the ventricular myocardium were modelled and corresponding BSPMs were calculated. DI BSPM was computed by subtraction of BSPM computed from normal activation from the BSPM computed from the activation with the presence of one or two lesions. Various morphological and statistical properties of DI BSPM were used as features for a discriminant analysis. Quadratic Fisher discriminant analysis with cross-validation was then used to determine the number of lesions in each case. Taking into account just one best performing feature, the overall error rate for distinguishing the number of lesions was 25.2%. Feature dimensionality was reduced by a feature selection algorithm resulting in 12 features as the optimal number for distinguishing DI BSPMs representing two lesions from maps representing a single lesion. The overall error rate was 4.1%, with partial errors 9.6% and 1.2% for misclassification of single or double lesions, respectively. Discriminant analysis based on exploitation of geometrical and statistical properties of integral BSPMs may be helpful in correct identification of the number of ischemic lesions.*

Keywords: *body surface potential maps; discriminant analysis; morphological and statistical map properties; number of lesions*

1. Introduction

Patients with ischemic heart disease and atherosclerosis may suffer from one or more simultaneously occluded coronary arteries. In [1] the method for localization of two simultaneous (double) lesions with changed repolarization from DI BSPMs was introduced. DI BSPMs from STT interval [2] were computed by subtracting the normal integral BSPM from an integral BSPM computed from the heart with one or two modelled lesions. However, for optimal use of this method it would be helpful to have preliminary information about the number of lesions in the examined heart.

Therefore in this study various characteristics of simulated DI BSPMs were employed to assess the information about the number of lesions. The aim of the presented paper is to suggest a method for discrimination between cases with single and double lesions with changed repolarization.

In our previous work [3] we suggested to distinguish the cases with two or one lesions from the features of the inverse solution results. Discriminant analysis was performed on both noiseless and noisy data. The best overall error rate for noiseless data was 5.9 % while employing 7 features derived from characteristics of dipoles that were obtained by the inverse solution. However, the inverse problem solution has appeared to be too complicated for the use in clinical praxis. Data for the discriminant analysis were prepared by a multiple step procedure.

Thus, we made an attempt to solve the same problem of distinguishing two from one lesion by a simplified procedure. The new procedure avoids rather demanding step of computing the

inverse solution and extracts characteristics for discrimination analysis directly from the modelled DI BSPMs.

The main idea was based on our expectations that two dipoles might create different DI BSPMs compared to single dipole in respect to maps' morphological and statistical properties. Projection of such disturbances through the body volume conductor should keep information about the number of disturbances. The philosophy is that this information is stored in DI BSPMs, regardless of the fact how we recover it - whether we use the inverse solution or a different approach. However, one may expect certain loss of this information especially in certain mutual positions and sizes of lesions, namely when positions of two lesions are in certain occultation.

2. Subject and Methods

One or two lesions in different positions in the ventricular myocardium were modelled and corresponding BSPMs were calculated on the surface of an inhomogeneous torso model using the multiple dipole cardiac generator. Details regarding heart and lesions simulation models were explained e.g. in [4]. Twelve combinations of two ischemic lesions were adopted, each with eight variations in size and shape. Together 96 pairs and 48 single lesions were modelled. BSPMs on an inhomogeneous torso model were computed using boundary element method [5].

DI BSPMs were used as input data for derivation and calculation of a number of features that were subsequently applied in the discriminant analysis task. The approach comes from an assumption that the maps might differ in both local and global properties. Various morphological and statistical properties of DI BSPMs were studied. The properties should not be dependent on absolute values of map potentials, thus in the first step DI BSPMs were scaled to fit into (-1,1) range of values.

Over 100 features were constructed and tested for performance in the discriminant analysis. Features were constructed in a systematic manner and covered much of all possible ways of measuring the map morphology. In the first step, from every single map representing normalized potential values, number of additional field maps was derived. The maps were constructed according to scalar and vector field operations: gradient (difference of neighbouring map values), divergence (subsequently from gradient field), Laplacian (representing second derivative). Moreover, in addition to construction of this new two-dimensional maps, one dimensional objects were created as well: Map projections in vertical and horizontal direction were processed in a form of mean values obtained from map columns or rows respectively.

Global statistical properties of the maps and their projections were then computed. Among them there were number of peaks (local extremes), minimum, maximum, mean, standard deviation, and central moments (extension of standard deviation into higher orders). Finally, distribution properties of map values were taken into account, being extracted from histogram shape and represented by a histogram based entropy and a length of histogram envelope. Mutual combinations of maps, projections, and statistical properties resulted in 112 different features.

In order to illustrate expected differences in selected features, double lesions might have, for example, higher number of local extremes in both maps and projections, higher mean gradient and mean laplacian in maps, and higher length of curves created by projection either in horizontal or vertical direction.

Two classes corresponding to one and two lesions were used in the discriminant analysis. Quadratic variant of Fisher discriminant analysis (QDA) suitable for unequal covariance matrices of multivariate normal distributions was applied [6]. The analysis was performed in the following testing mode: a cross-validation technique was applied in a form of repeated random sub-sampling validation. In 1000 trials 80% of available data was randomly chosen for training and remaining 20 % for validation. A Classification rule was obtained during the training. The classification outcome was obtained as the number of correctly and incorrectly classified single and double lesions. A feature selection was applied in order to reduce the data dimensionality and to simplify the data evaluation. Greedy forward selection algorithm was used by adding the best feature at each round [7].

3. Results

Taking into account just one best performing feature, the overall error rate for distinguishing number of lesions was as high as 25.2 %. Single most effective feature was *gradStdev*. Its discriminative potential in combination with the second feature *projCurveA* yielded error rate of 17.9 % (see Fig.1). Feature *gradStdev* was derived from the standard deviation of a gradient field map, while feature *projCurveA* is associated with the length of curves created by projections in both vertical and horizontal direction (curves' points are data means from corresponding columns or rows). Further increase of the number of involved features improved the discriminative performance up to the number of 12 (see Fig.2). The overall error rate for the best set of 12 features was 4.1 %, with partial errors of 9.6 % for misclassification of single lesions and 1.2 % for misclassification of double lesions.

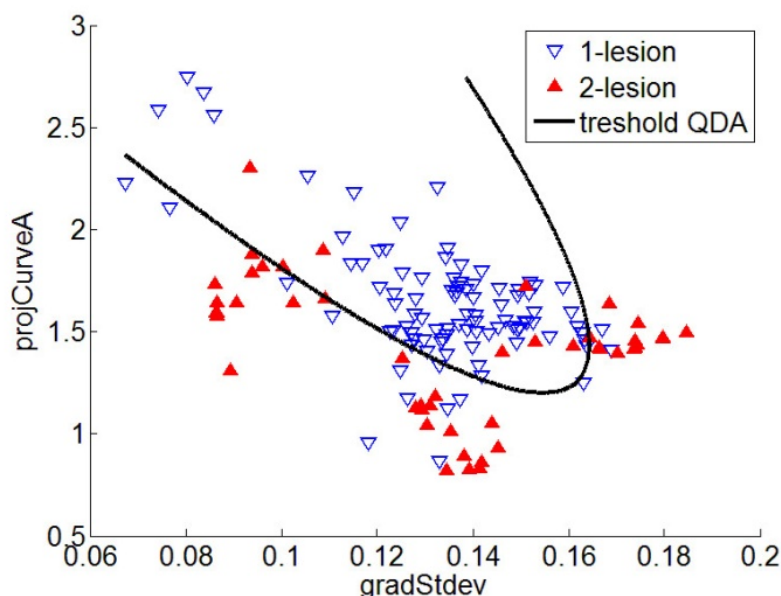


Fig. 1. Quadratic discriminant analyses. Two best performing features in 2 dimensional feature space with overall error 17.9 %.

4. Discussion and Conclusions

The method was applied on 144 cases of simulated data (96 cases of two lesions and 48 cases of one lesion). In distinguishing between one or two simultaneous lesions our newly proposed method over-performed our previous more complicated approach that employed inverse solution [3]. While for the set of 7 features both approaches obtained the same error rate of 5.9 %, only the new method further increased its accuracy and achieved 4.1 % error when 12 selected features were used.

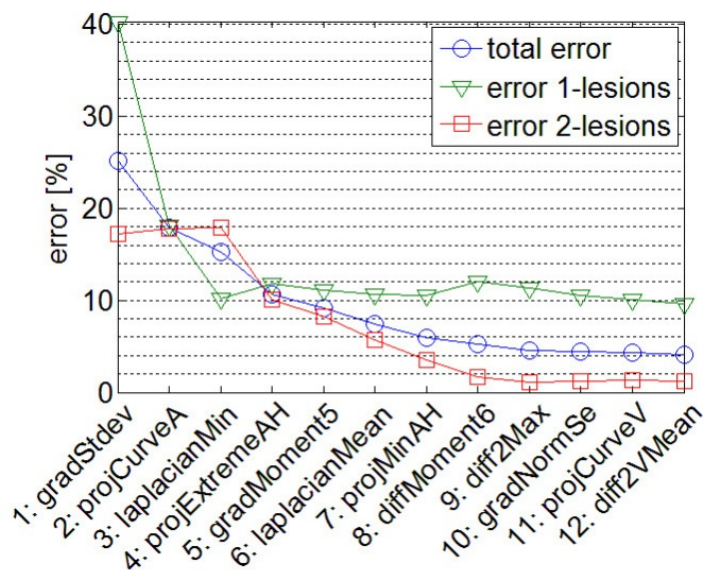


Fig. 2. Quadratic discriminant analyses. Performance of the most effective set of features according to the number of features used. Set of 12 features yielded minimal total error of 4.1 %.

Besides noiseless maps, discriminant analysis between maps with added 20 dB noise was performed as well. Discriminating accuracy remained at the same level of errors. For our future analysis we intent to apply different types of noise, namely noise derived from electrode position uncertainties and from dipole moments that represent the lesions. Discriminant analysis based on exploitation of morphological and statistical properties of integral BSPMs may be helpful in successful identification of number of local electrical sources in the heart ventricles.

Acknowledgements

This work was supported by research grants No. 2/0131/13 and 2/0043/13 from the Vega Grant Agency in Slovakia, by grant No. APVV-0513-10 from the Slovak Research and Development Agency and by project Biomedicine University Research Park Bratislava (ITMS code 26240220087).

References

- [1] Svehlikova J, Lenkova J, Turzova M, Tysler M, Kania M, Maniewski R. Influence of individual torso geometry on inverse solution to 2 dipoles. *J Electrocardiol*, 45:7, 2012.
- [2] Svehlikova J, Kania M, Turzova M, Heblakova E, Tysler M, Maniewski R. Identification of Ischemic Lesions Based on Difference Integral Maps, Comparison of Several ECG Intervals. *Meas Sci Rev*, 9:117–21, 2009.
- [3] Svehlikova J, Teplan M, Tysler M. Classification of Inverse Solutions to Two Dipoles. *Computing in Cardiology*, 40:1127-1130, 2013..
- [4] Svehlikova J, Tysler M. Noninvasive finding of local repolarization changes in the heart using dipole models and simplified torso geometry. *J Electrocardiol*, 46:4, 284-288, 2013.
- [5] Barr RC et al.. Determining Surface Potentials from Current Dipoles, with Application to Electrocardiography. *Ieee Trans Biomed Eng*, 13:88, 1966.
- [6] Therrien C. Decision, Estimation and Classification: an Introduction to Pattern Recognition and Related Topics. John Wiley and Sons, New York, 1989.
- [7] Theodoridis S, Koutroumbas K. Pattern recognition. Academic Press, San Diego, 4th ed., 2006.