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VULNERABILITY INDEX IN DIFFERENT CONTROL GROUPS OF THE SAME AGE

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Abstract

The vulnerability index (VI) is a parameter evaluating the risk of arrhythmia development derived from isointegral maps. It is the spatial analogue of the ventricular gradient that expresses inhomogeneity of ventricular repolarisation. We compared values of VI of different groups of young people of the same age to determine the variability of VI caused by different control groups.

We constructed isointegral maps (IIM) of the QRS complex, ST-T and QT interval (IIM STT, IIM QRST) of 83 young people at the age of 18–19 years. We divided the subjects randomly into two groups (group A: 24 women, 18 men; group B: 23 women, 18 men). The examined persons had no history of any cardiovascular disease and standard ECG was without pathological changes. VI was calculated for each individual ("test"), while all the other members of the given group served as comparison subjects ("control"). Except the VI we also compared the optimisation coefficient alpha and the number of valid comparisons.

We found no significant differences between both groups (vulnerability index VI: A: 8.15 mV.ms (4.84 mV.ms–11.13 mV.ms) versus B: 8.17 mV.ms (7.29 mV.ms–9.12 mV.ms); alpha A: 0.829 (0.723–0.914) versus B: 0.772 (0.644–0.857); number of valid comparisons A: 25.8 ± 11.5 versus 24.9 ± 12.6).

Since the differences between both groups were not significant, we concluded that we could use different groups of the same age to calculate the VI.

Key words

Electrocardiographic body surface mapping, Vulnerability index, Isointegral map

INTRODUCTION

There are several methods to evaluate the risk of arrhythmias. The QT interval has long been considered to be a suitable marker of prolonged repolarisation. Later studies (*1*) comparing QT intervals measured on the chest surface and ventricular repolarisation directly on the heart showed a low correlation between the activation-recovery interval on the heart surface and the QT interval as well as low sensitivity to local changes of repolarisation.

Electrocardiographic body surface mapping offers more possibilities for arrhythmia evaluation. It can be simply the number of extrema in the QRST

isointegral map (IIM) (*2*) or, more sophisticated, the index of vulnerability (VI) based on a comparison of IIM QRST (representing the whole QT interval) of a test subject with IIM QRS (QRS complex) and IIM STT (ST-T interval) of a control. IIM QRST represents the ventricular gradient, which describes the distribution of repolarisation properties and is independent of the activation sequence (*3*), which is represented by IIM QRS. The difference between IIM QRST and the sum of IIM QRS plus IIM ST-T then corresponds to those repolarisation inhomogeneities that are not caused by activation sequence.

This approach was used by *Urie et al* (*4*), who calculated the VI of dogs before and after the application of arrhythmia-inducing factors. Several works applied this method on humans (*5, 6*), but the diagnostic use of this approach is more complicated, since there is no "control map" in the healthy state of a given patient available, so that the control map has to be taken from the healthy population (controls).

Our aim was to determine differences in the VI between groups with similar composition regarding age and sex, which is an important step to create a control group suitable for calculation of the VI of the patients.

SUBJECTS AND METHODS

The degree of disparity of ventricular recovery, expressed on IIM QRST, is proportional to the risk of ventricular arrhythmia (*4*). The isointegral map is the distribution of time-voltage integrals over the chest during a chosen interval, e.g. QRS complex or QT interval. The IIM QRST of the patients are compared to nonvulnerable healthy samples of a control group and the best matching map is determined, i.e. a map with the smallest total QRST area difference from all leads. This is constructed as the "vulnerability map" V according to the equation:

$$V = QRST_{test} - (QRS_{control} - a \cdot STT_{control}) \quad (1)$$

where α is the minimising (optimisation) coefficient determined by minimising the squared difference:

$$\frac{d(V^2)}{da} = 0 \quad (2)$$

This minimising coefficient α has to fulfil the condition:

$$-1 \le a \le 1 \quad (3)$$

The vulnerability index itself is then calculated as the root mean square of the sum of the squares of all values contained in the vulnerability map:

$$VI = \sqrt{\frac{\sum_{i=1}^{N} V_i^2}{N}} \quad (4)$$

where V_i is the value of the vulnerability map in the i-th position, $i = 1, 2, ..., N$, N is the number of leads (grid points in the map).

For ECG registration we used the limited 24-lead system after Barr implanted in the mapping system ProCardio (*7, 8*). The electrocardiograms were registered in supine position. A linear baseline was taken through T-P segments. The onset and offset of the QRS complex and the offset of the T wave were established manually from the root mean square signal (*9*).

We constructed the IIM QRS, IIM STT, and IIM QRST of 83 young people at the age of 18–19 years. The subjects were randomly chosen among students of the Faculty of Medicine, Comenius University in Bratislava. They were randomly divided into 2 sex-matched groups (group A: 24 women, 18 men; group B: 23 women, 18 men). None of the subjects had a history of any cardiovascular disease and all had standard ECGs without pathological changes.

Each subject from both groups was tested against all the remaining subjects from his or her group. Comparisons of the identical subject taken as "test" and as "control" at the same time were excluded as well as all comparisons with $|\alpha| > 1$. The minimal value VI of all valid comparisons, i.e. $|\alpha| \leq 1$, for each subject was taken as the vulnerability index for statistical comparison. We also analysed the value of the corresponding minimising coefficient α and the number of valid comparisons for each test subject.

The group values were statistically analysed. They are expressed either in the form of means ± 1 standard deviation or in the form of medians with a 95% confidence interval. The values for the number of valid comparisons were compared using an unpaired two-tailed t-test. Since the vulnerability index and the minimising coefficient did not have normal distribution, we used the Mann-Whitney test to compare the medians of the two samples. The difference between the groups was taken as statistically significant for $p < 0.05$ or less.

RESULTS

Examples of maps used for VI calculation are given in *Fig. 1*. The similarity between both IIM QRST maps is very high. This explains the low value of the VI obtained.

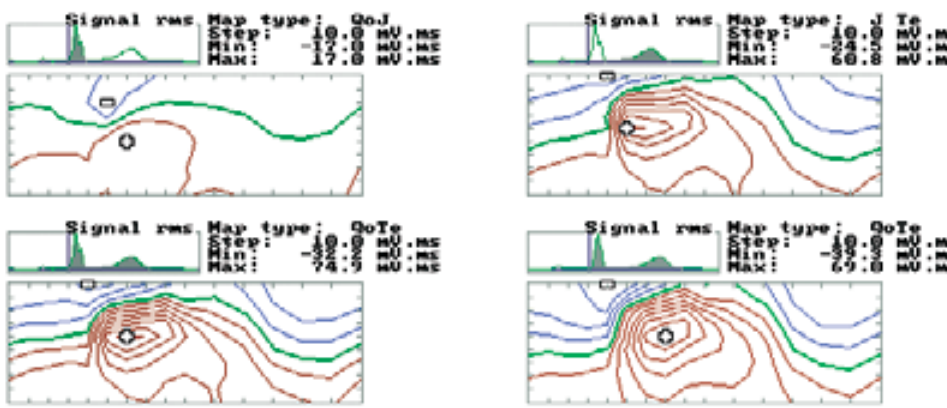

Fig. 1

Isointegral maps from which the lowest VI was calculated (VI = 3.59 mV.ms; $\alpha = 0.594$; test: woman, control: woman). In the upper row are the maps of the control subject: IIM QRS (QoJ) and IIM ST-T (JTe). In the lower row are the maps of the control subject on the left and the test subject on the right, in both cases IIM QRST (QoTe). The reference lead (II limb lead) with the integration area is depicted above each map.

We found no significant differences between the two groups (vulnerability index VI: A: 8.15 mV.ms (4.84 mV.ms–11.13 mV.ms) versus B: 8.17 mV.ms (7.29 mV.ms–9.12 mV.ms); coefficient alpha: A: 0.829 (0.723–0.914) versus B: 0.772 (0.644–0.857); number of valid comparisons: A: 25.8 ± 11.5 versus B: 24.9 ± 12.6).

DISCUSSION

The vulnerability index is defined as the root mean square of the vulnerability map. Since it is the spatial equivalent of the ventricular gradient, which supposes that the repolarisation sequence is independent of the depolarisation sequence, it allows to detect primary and secondary repolarisation properties.

In our study we compared two age- and sex-matched groups with equal sample numbers. We found no significant differences between the two groups as expected.

The value of the vulnerability index may depend on some other factors as well, e.g. age or number of subjects in the control group.

The age dependence of the vulnerability index was analysed in another study (*10*). Two sex-matched groups of different age were studied, each involving 26 men and 3 women; group A: 18–19 years, group B: 20–25 years. There were no significant differences between these groups, neither for VI values, nor for the minimising coefficient, or for the number of valid comparisons. The VI medians (95% confidence interval) were: A: 9.92 mV.ms (8.11–11.96 mV.ms) versus B: 9.88 mV.ms (8.30–12.87 mV.ms). From this study it follows that the VI value is independent of the age of the control group. This is probably valid only for a small age difference and has to be confirmed in a study with an older control group.

The smaller values of VI in the present study may be caused by larger samples of evaluated groups. This has to be confirmed and then considered for creating a suitable control group for comparison with the patients. These types of study have not been published yet.

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INDEX VULNERABILITY V RÔZNYCH KONTROLNÝCH SKUPINÁCH PROBANDOV ROVNAKÉHO VEKU

Súhrn

Index vulnerability (VI) je parameter kvantifikujúci riziko vzniku arytmie na základe repolarizačných zmien a počítaný z izointegrálových máp (IIM). Je to priestorový ekvivalent komorového gradientu. Jednotlivé charakteristiky IIM sú však ovplyvnené rôznymi faktormi ako vek alebo pohlavie, ktoré prispievajú k relatívne vysokej variabilite u pacientov aj v kontrolných skupinách. V našej štúdii sme sledovali, ako sa prejaví faktor rôznych skupín probandov rovnakého veku.

Unipolárne elektrokardiogramy pre konštrukciu máp sme merali 24-zvodovým systémom podľa Barra implantovanom v mapovacom zariadení ProCardio. Zostrojili sme IIM QRS (komplex QRS), IIM STT (interval ST-T) a IIM QRST (interval QT) 83 mladých ľudí vo veku 18–19 rokov a rozdelili náhodným výberom na 2 skupiny (skupina A: 24 žien, 18 mužov; skupina B: 23 žien, 18 mužov). Nikto z vyšetrovaných osôb nemal v anamnéze kardiovaskulárne ochorenie a všetci mali EKG v norme. VI sme počítali pre každého jednotlivca („test“) tak, že všetci ostatní členovia skupiny slúžili ako porovnávacie subjekty („kontrola“).

VI sa vypočíta ako stredná kvadratická hodnota mapy vulnerability, ktorá je daná minimalizovaným rozdielom IIM QRST testovaného subjektu a súčtu IIM QRS a IIM STT kontrolného subjektu, pričom vklad IIM STT sa optimalizuje pomocou koeficientu alfa (α). Na ďalšiu analýzu sme vybrali najnižšiu hodnotu z vyhovujúcich VI. Porovnávali sme vypočítané hodnoty VI a zodpovedajúce hodnoty α, ako aj počet platných porovnaní, t.j. pre $|\alpha| \leq 1$.

Medzi jednotlivými skupinami sme nenašli signifikantné rozdiely (index vulnerability VI: A: 8.15 mV.ms (4.84 mV.ms–11.13 mV.ms) voči B: 8.17 mV.ms (7.29 mV.ms–9.12 mV.ms); koeficient α: A: 0.829 (0.723–0.914) voči B: 0.772 (0.644–0.857); počet platných porovnaní: A: 25.8 ± 11.5 voči B: 24.9 ± 12.6).

Porovnanie rôznych skupín rovnakého veku viedlo k nesignifikantným rozdielom. Z toho usudzujeme, že pri výpočte indexu vulnerability môžeme používať rôzne kontrolné skupiny pri zachovaní rovnakého veku a rovnakého zastúpenia pohlaví.

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