SPATIAL DISTRIBUTION OF QT INTERVALS IN BODY SURFACE POTENTIAL MAPS FROM LIMITED LEADS

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Possibility to use body surface potential maps from limited lead sets for assessment of spatial distribution of repolarization times was tested. QT intervals and activation recovery intervals (ARI) were computed from both, single beat and averaged ECG. Spatial distributions of QTI and ARI obtained from 192, 63 and 32 leads were presented as body surface interval maps. Data from a group of healthy subjects and a group of patients after myocardial infarction (MI) were analyzed.

QT interval map patterns obtained from 192 leads were in agreement with results published for averaged full grid maps. QT interval dispersions obtained from mapping leads suggest their possible better estimation than from standard precordial leads. However, reproducibility of QT interval maps was not satisfactory, namely in the right lateral and posterior torso with low amplitude ECGs, so the reliability of the obtained spatial information is questionable. Maps constructed from only 32 leads revealed considerable lost of information in the reconstructed areas without leads.

Reproducibility of ARI maps was much better than that of QT maps and they were estimated from limited number of leads better than QT maps. From the results it seems that ARI maps might be more appropriate to give some insight into the spatial distribution of the repolarization process. However, their interpretation needs additional study.

1. INTRODUCTION

It is widely accepted that inhomogeneity of myocardium repolarization is one of the factors connected with increased risk of ventricular arrhythmias. Direct arrhythmic indications that could be obtained by local tracing of refractory periods e.g. by measurement of monophasic action potential (MAP) [1] have limited applicability to clinics and reliable non-invasive methods for determining of repolarization characteristics are still to be found. The basis of several ECG-based methods is the measurement of time intervals between features that denote the time of tissue depolarization and recovery. The most widespread method is measurement of QT intervals (QTI) measured between some measure of beginning of the QRS complex and the T-wave end. The spatial dispersion of QTI is highly analyzed and many reports over the past decade documented its usefulness to identify cardiac patients with poor prognosis. Distinct spatial QTI distributions that are consistent with known regional myocardial electrophysiology were also reported [2]. However, latest studies suggest limited reliability of the method and other ECG time intervals that are more strongly related to MAP measurements were proposed.

Different method for detecting activation and recovery times in the heart was elaborated in [3]. Based on relation between action potentials and observed surface ECG potentials under simplified and idealized conditions, authors proposed to evaluate the activation recovery interval (ARI) measured between the most negative slope in the QRS complex and the most positive slope of the T wave. Despite of smoothing effect of the torso volume conductor, at least the heart close precordial leads showed high correlation with ARI recorded epicardially [4].

The aim of our study was to test the possibility of non-invasive assesment of local repolarization properties from spatial distributions of QT and AR intervals measured in surface ECG leads used for body surface potential mapping, to analyze the reproducibility of these time interval maps and to test their capability to reflect spatial distribution of the repolarization in the myocardium.

2. METHOD AND MATERIAL

We analyzed the spatial distribution of QTI and ARI using body surface potential mapping (BSPM) techniques. ECG signals were measured from 32 leads (according to Lux, set 32a), 63 leads (according to Savard) and 192 leads (in 16x19 grid) using the ProCardio mapping system [5]. When 32 or 63 leads were used, potentials in the full mapping grid were first computed using the particular reconstruction algorithm for that limited lead set. Spatial distributions of QTI and ARI were constructed by calculating the intervals at each mapped site and displayed as body surface interval maps.

Several techniques for automated identification of Q-onset and T-end discussed in literature (e.g. [6]) were tested for calculation of QTI. In presented study, Q-onset was determined as crossing of constant threshold of the signal derivative, T-end was found as crossing of derivative threshold depending on the last signal extreme. ARI were determined as intervals between the most negative derivative in the QRS complex and the most positive derivative in the T wave.

QTI and ARI values obtained by automated algorithms were visually inspected and manually corrected. Spatial distribution of intervals in individual patients was analyzed. Intervals were not corrected for heart rate. To facilitate comparison among subjects, besides absolute intervals also mean values and standard deviations of mapped intervals were computed and normalized maps were constructed.

Two groups of subjects selected from a large file were studied. There were 7 normal subjects in the first group, 5 were measured using the 32-lead set and 2 subjects were measured using the 63-lead set. Similarly, in the second group of MI patients, 32-lead ECG data were measured in 5 patients and 63 leads in 2 patients. For selected subjects, ECG signals in 192 mapping leads (4 groups of 48 leads) were measured. Both, single beat and averaged ECG data (60 seconds) were evaluated to check the reliability and reproducibility of the computed maps.

3. RESULTS

Spatial QTI distributions in a group of healthy subjects and a group of patients after myocardial infarction (MI) showed patterns that were in agreement with previously published results for averaged full grid maps [2]. In normal subjects, shortest QT intervals over the right inferior chest and longer intervals over the right superior and left lateral torso were observed. Spatial QTI distribution in post-MI patients deviated from the normal pattern, displaying rise in QT duration over specific areas, which could reflect functional and morphological disturbances. However, the QTI map patterns were often fragmented, suggesting possible inaccuracies of QTI measurements. Examples of QTI maps in a normal subject and a patient with anterior Q-MI are shown in Fig.1.

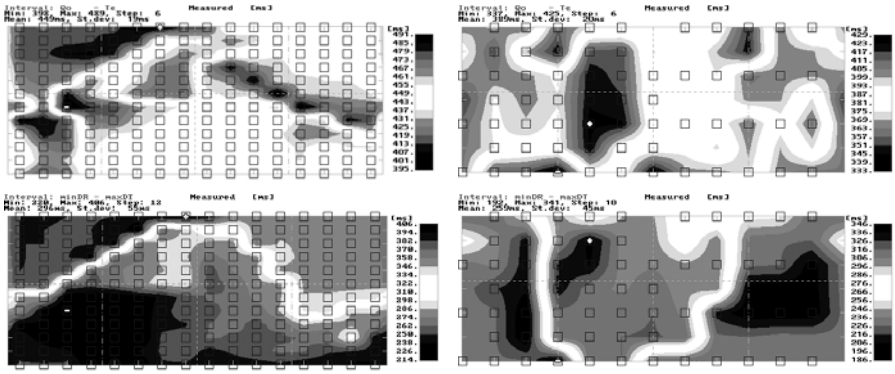

Fig.1. Examples of QTI (upper) and ARI maps (lower) in a normal subject (left) and in a patient with anterior Q-MI (right). Maps were constructed from marked 192 or 63 leads.

Comparison of QTI maps computed from different measurements showed their poor reproducibility (correlation less than 0.5) that was caused mainly by the difficulties in evaluating T-wave end in leads with low potentials. Comparison of QTI maps computed from averaged 192 leads with maps obtained from single beat data or from 32 leads showed lower correlation and increased rms errors suggesting increasing influence of noise in single beat measurements and possible lost of information in measurements from limited lead sets. For a normal subject, these results are summarized in Table 2.

Accuracy of QTI dispersion defined as the difference between the longest and the shortest QT interval estimated from different lead sets was checked for subjects measured in 192 leads. QTI parameters obtained from a normal subject are shown in Table 1. QTI dispersion was apparently underestimated if only leads corresponding to standard precordial electrodes V1 to V6 were used and increased with increasing number of leads. However, there was no more substantial change between QTI dispersion estimated from 63 and 192 leads.

Leads	6	32	63	192
QT parameter	(V1 - V6)	(Lux 32a)	(Savard)	(grid 16x12)
Minimum	438	415	407	397
Maximum	472	481	491	484
Mean	453	455	453	447
Standard deviation	14	18	16	18
Dispersion	34	66	84	87

Table 1. QTI parameters in [ms] estimated from different lead sets in a normal subject.

ARI maps in normal subjects exhibited longer intervals over the right superior and posterior chest and shorter intervals over the right inferior chest wall. In post-MI patients the patterns were changed and positions of prolonged ARI were related to the diseased part of the heart. Examples of ARI maps are in Fig.1.

Map patterns representing spatial ARI distribution were much more compact than the QTI patterns and were stable over long time: in some cases measurements were repeated after 3 years with good reproducibility. Changed ARI patterns after successful PTCA (Fig.2) might reflect underlying electrophysiological changes.

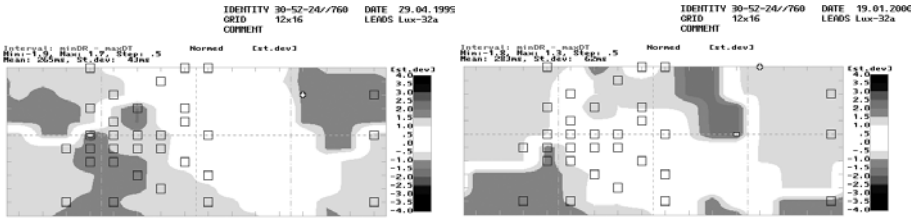

Fig.2. Normalized ARI maps from a patient with antero-septal non-Q MI before (left) and after successful PTCA (right).

Comparison of ARI maps computed from averaged 192 leads with maps obtained from single beat data or from 32 leads showed increased rms error but still very good correlation (about 0,9) suggesting acceptable reproducibility and possibility to estimate ARI maps from limited number of leads. Results of this comparisons for a normal subject are summarized in Table 2.

Compared intervals	QTI		ARI	
	correlation	Rms error [ms]	correlation	rms error [ms]
192 leads, single beat	0.46	19	0.94	22
32 leads, averaged	0.40	23	0.90	26
32 leads, single beat	0.24	22	0.89	31

Table 2. Comparison of QTI and ARI maps in normal subject computed from 192 leads averaged over 60 seconds (used as reference) to maps computed from single beat data and from limited sets of leads.

4. DISCUSSION AND CONCLUSIONS

Applicability of QTI mapping may be limited by the problems of finding the T wave end that is very complex. It is the source of unavoidable errors, especially in leads with low potentials. Moreover, possible local T wave shortening can be overlaid by projections from neighboring heart areas. Therefore evaluation of QTI from BSPM leads can give more reliable estimation of QTI dispersion than standard 12-lead ECG but the possibility of the spatial QTI distribution to reflect local repolarization changes is questionable.

Reproducibility of ARI maps was much better than that of QTI maps in all examined lead sets and the spatial distribution of ARI was reconstructed from limited number of leads better than the QTI distribution. Although the resolution of surface mapping is in principle limited by the smoothing effect of torso, we hope that surface ARI maps might give some insight into the spatial distribution of the repolarization process. However, additional study is needed for their interpretation. More detailed analysis of T wave morphology and of spatial smoothness of the ARI parameter could allow better identification of local repolarization changes.

Major limitation of our study is the small number of evaluated cases and possible methodological errors caused by the fact that full grid data were measured sequentially in 4 groups of 48 leads. Nevertheless, the study suggests that QTI mapping is methodologically and technically not a good choice for characterizing local variations of repolarization and ARI mapping seems to be more promising.

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