Spatial Variability of Ventricular Activity Intervals in Normal Subjects and Old Myocardial Infarction Patients

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Abstract – Increased dispersion of QT interval in the 12-lead ECG have been proposed as risk factor of ventricular arrhythmias in post myocardial infarction (post-MI) patients, but its sensitivity and specificity is low for diagnosis and/or prognosis. We evaluate dispersion in other ventricular activity intervals, in order to determine whether they improve the separation between 15 normal subjects and 15 post-MI patients compared with QT dispersion. All the interval ventricular activity dispersions measured in the Frank's orthogonal leads (XYZ) are larger in post-MI patients than in normal subjects, but the differences are significant only for JTpeak (JTp) dispersion ($p = 0.03$). Therefore JTp dispersion could improve the identification of post-MI patients with risk of ventricular arrhythmias.

I. INTRODUCTION

An increase in the spatial variability of the QT interval between leads, named QT dispersion (QTd), is considered a risk factor for malign ventricular arrhythmias in post-MI patients [1-4], but there is no agreement about its prognostic value [5-7], due in part to differences in the methods used to measure QTd in the 12-lead ECG [8-10]. This index is affected by: an inaccurate measurement of the QT interval because of different definitions for the end of the T wave (with and without U wave); heart rate (HR); autonomic tone; no simultaneous recordings and measurement leads used.

Other intervals of ventricular activity have been considered to assess the risk of malign ventricular arrhythmias in post-MI patients. The JT interval better describes the duration of the repolarization than the QT when there is a prolongation of the QRS interval in patients [11]. Moreover, its dispersion (JTd) is a better predictor of arrhythmia-induced cardiac death than the QTd [6]. On the other hand, a QRS prolongation can contribute to the risk of cardiac death independently of repolarization abnormalities [6]. An abnormal dispersion of the excitation could also increase the risk of ventricular arrhythmias [12], and it has been shown that the dispersion of the QRS complex (QRSd) is larger in post-MI patients than in healthy individuals [13].

The QTp interval (from Q wave onset to T wave apex), comprises more than 50 % of the ventricular repolarization and is easier to measure than the QT interval. However, its suitability as a measure of the repolarization instead of the QT remains unclear because it is known that the Tpe interval (from T wave apex to T wave end), is influenced by disease and exercise, yet its variation is not reflected in that of the QTp interval [14].

The Tpe interval corresponds to the final part of the repolarization and it has been proposed as a more representative measure of the ventricular repolarization, because it is less dependent on autonomic modulations, HR, and QRS duration than the QT and QTp intervals [15]. Furthermore, it has been experimentally shown that it correlates with the dispersion of the repolarization [16], and it has been hypothesized that it represents the transmural dispersion of the repolarization [17].

Although it has been reported that the QTp and Tpe intervals are larger in patients with MI than in normal individuals, those differences were only significant for the QTp interval [18]. A different study in patients with coronary artery disease susceptible to ventricular fibrillation also showed a significant increase in the dispersion of the intervals QTp and Tpe but not the QT, JT and JTp compared to controls. Nevertheless, because there was a considerable overlap between the studied groups, that measurement does not provide a useful clinical information to identify patients with risk of sudden cardiac death [19].

The objective of this work is to evaluate dispersion in other ventricular activity intervals, in order to determine whether they improve the separation between normal subjects and in patients with old myocardium infarct (OMI), compared with QT dispersion.

II. METHODS

1) Subjects and data acquisition

The study group was 15 normal subjects (12 men, 3 women; age 40 ± 12 years) and 15 OMI patients (10 men, 5 women; age 43 ± 14 years). The difference in age between both groups was not significant. The mean HR was (70 ± 9) beats/min in normal subjects and (68 ± 8) beats/min in OMI patients. This difference is not significant and therefore the influence of HR in both groups is similar. Of the 30 records analyzed, 8 were obtained from normal subjects at rest where 12 simultaneous derivations were amplified (programmable gain from 500 to 2500, bandwidth 0.025 Hz to 500 Hz) by a proprietary high-resolution electrocardiography system [20]. The ECG signals were sampled for 5 min at 1000 samples/s by a 12 bit, plug-in PC card (DT21EZ, Data Translation) controlled by Asyst[®].

The remaining 22 records belonged to the two 15-lead CSE (Common Standards for Quantitative Electrocardiography) data bases (12-lead ECG plus Frank's orthogonal XYZ leads) [21]. These databases are available for testing and development of ECG wave recognition and measurement programs, and consist of a set of ECGs with different morphologies, normal as well as pathological (OMI). Thirteen of these records were from the 3-lead data base (3 leads recorded simultaneously) and nine were from the multilead data base (15 leads recorded simultaneously).

In the pathological records with OMI, the infarct was located by means of the ECG for all the patients. There were 10 inferior infarcts and 5 anterior infarcts. The criteria used to diagnose an OMI were a pathological Q wave longer than 40 ms or a minimal amplitude larger than a fourth of that of the QRS complex and an isoelectric ST segment [22]. All records had a normal sinus rhythm and none had complete His bundle branch block.

2) Data processing and analysis

The algorithms to detect the points of interest in the QRS complex and T wave, necessary to measure the different time intervals, were based on the wavelet transform [23]. The validation process of the 3 designed algorithms was performed using 25 records of the well annotated reference database for ECG measurement, the CSE multi-lead measurement database [21], in which the gold standard was derived by an international group of cardiologists, who visually determined the on- and -offset points of P, QRS and T waves [24]. In these 15-lead records the earliest onset (QRS) and the latest offsets (QRS and T wave) of each record were detected, and the measurements were within the tolerance limits for deviations with respect of the manual measurements determined by the CSE experts [25].

The following intervals were measured for each subject: QT (from Q wave onset to T wave end, defined as the return to the isoelectric line), QTp (from Q wave onset to T wave apex), QRS (from Q wave onset to S wave end), JT (from S wave end to T wave end), JTp (from S wave end to T wave apex) and Tpe (from T wave apex to T wave end).

The leads selected to analyze the dispersion of ventricular activity were: the Frank's orthogonal leads (XYZ) in the 22 records from the CSE data bases, and the equivalent set of quasi-orthogonal leads D1, aVF, and V2 [26], for the 8 records from normal subjects at rest. The dispersion was measured for each subject as the difference between the maximal and minimal interval of the three selected leads. The leads with low T-wave amplitude or affected by artifacts were discarded and replaced by the topographically adjacent lead. The measurements of dispersion were not corrected with respect to HR [19]. The dispersion of the intervals of ventricular activity, corresponding to normal subjects and patients with OMI, were compared by the Wilcoxon rank sum test. Two-tailed $p < 0.05$ was considered statistically significant.

III. RESULTS

Tables 1 and 2 show the mean (m), standard deviation (sd) and level of significance (p) of the dispersions of the ventricular activity intervals in normal individuals and in OMI patients. All the dispersions were larger in patients than in normal subjects. Nevertheless, these differences were significant only for the dispersion of the JTp interval [(37 ± 14) ms versus (24 ± 15) ms, $p = 0.03$].

Table 1. Dispersions of the ventricular activity intervals in normal subjects.

Normal	QT	QTp	JT	JTp	Tpe	QRS
S1	28	42	22	51	49	9
S2	27	12	8	8	16	19
S3	9	8	21	15	16	16
S4	9	33	14	35	24	10
S5	26	7	31	37	25	35
S6	36	31	16	40	41	32
S7	19	9	15	26	11	33
S8	14	9	4	4	7	13
M1-088	26	41	13	39	28	17
M1-099	2	8	10	4	10	8
M1-101	7	40	18	31	49	9
M1-125	34	26	35	27	8	18
M2-098	21	10	7	7	11	17
M2-104	16	3	19	10	18	9
M2-105	23	18	25	31	28	13
m $\pm$ sd	20 (10)	20 (14)	17 (9)	24 (15)	23 (14)	17 (9)

Intervals are in milliseconds; m, mean; sd, standard deviation.

Table 2. Dispersions of the ventricular activity intervals in OMI patients.

Patients	QT	QTp	JT	JTp	Tpe	QRS
M1-091	18	37	27	44	40	9
M1-114	34	11	20	36	45	25
E1-006	56	48	57	49	21	8
E1-009	10	31	8	40	36	18
E1-024	22	23	10	28	38	17
E1-025	13	10	17	30	13	21
E1-026	25	29	9	58	50	29
E1-066	34	16	20	44	44	44
E1-118	8	19	46	41	18	38
E1-124	61	21	53	44	69	23
E2-020	11	9	4	12	9	10
E2-073	24	36	33	57	38	21
E2-080	12	14	22	27	5	20
E2-116	16	21	4	8	8	20
E2-119	41	26	29	31	35	17
m $\pm$ sd	26 (16)	23 (11)	24 (17)	37 (14)	31 (18)	21 (10)
p	0.53	0.26	0.36	0.03	0.25	0.12

Intervals are in milliseconds; m, mean; sd, standard deviation;

p values are from the Wilcoxon rank sum test.

IV. DISCUSSION

The increase of QT dispersion reflect an increase in the heterogeneity of the ventricular repolarization pattern, which is associated with malign ventricular arrhythmias in post-MI patients. Nevertheless, different studies differ on its prognostic importance, mainly because of controversies in the measurement methods in the 12-lead ECG. The accuracy of the measurement of QTd depends on the accuracy of the measurement of the QT interval [9], therefore there are many factors that influence the results for QTd: different definitions for the T-wave end (with and without U wave), HR, the autonomic tone, and the selected leads [8-10].

In this study, some relevant factors influencing the duration of the QT interval, such as age, gender, and HR, do not contribute any significant difference. The orthogonal leads (X, Y, Z) and their equivalent set of quasi-orthogonal leads (D1, aVF, and V2) have been used to measure the QTd dispersion, because they provide the same information that the QTd measured in the 12-lead ECG [26].

With regard to the accuracy of the measurement of time intervals, particularly the T-wave end, an automated and robust computer algorithms have been developed using wavelet analysis to accurately detect the designed computer algorithms to detect the points of interest of the QRS complex and T waves. These algorithms were validated using the CSE multi-lead measurement database [21], and the measurements were within the tolerance limits for deviations with respect to the measurements by experts [25].

In agreement with previous studies, the dispersions of all the ventricular activity intervals considered were higher for OMI patients than for healthy subjects [6,13,19], but the difference was only significant for the dispersion of the JTp interval. Because the dispersion of the QRS interval in both groups does not have any significant difference, the increase of the dispersion in patients can be attributed to an increase in the heterogeneity of the duration of the action potential, but not to regional variations in the activation time. This confirms the value of the JTp interval and suggests that the T-wave morphology reflects changes in the repolarization that result from chronic infarct and ischemia [18].

Since most of the sudden deaths from arrhythmia have an ischemic origin, JTp dispersion could improve the identification of post-MI patients with risk of malign ventricular arrhythmias.

ACKNOWLEDGEMENTS

This work has been funded by a scholarship from the CONACYT (México) to Carlos Alvarado-Serrano and by project SAF98-0120 from the Spanish CYCIT.

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