Longitudinal Modifications of T-Loop Morphology

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Abstract

Serial analysis is performed to evaluate longitudinal modifications of electrocardiographic parameters concerning morphology variations of repolarization phase, using the vectorcardiogram (VCG). The orthogonal Frank leads were synthesized from the standard 12 lead ECG. For this purpose, five parameters were obtained from the VCG with two different methods of considering the zero point.The population based ECG-ILSA database (Italian Longitudinal Study on Aging) was used. All the patients present both in t_1 and t2=t1+5 years were considered, and those classified as healthy (147), with cardiac diseases (77), with hypertension (219), with angina pectoris (44) and with MI (51) were included in this study. The observed results show a stability T-loop morphology measurements in a temporal interval of 5 years. In addition, the Angina Pectoris group, characterized by a high "clinical instability" showed the most significant longitudinal modifications.

1. Introduction

Several recent publications aroused the interest in T-wave morphology [1-4].

In addition, the possibility to store more than one ECG of the same patient acquired at different times, permits to perform the serial ECG analysis to determine and quantify the ECG measurement and diagnostic temporal modifications. In clinical practice this analysis is very helpful especially for quantifying the evolving of diseases or in the follow-up of particular groups.

The aim of this study is to investigate the longitudinal modifications of T-loop morphology parameters. For this purpose the ECG database from the longitudinal ILSA study has been used. The group patients present both in t_1 and t_2 (t_2= t_1+5 years) has been considered. Five parameters obtained from the synthesized VCG were computed with two methods, and a validation study was performed.

2. Material and methods

Particular aspects of T-wave morphology are considered for characterization and quantification of heterogeneous repolarization, using the vectorcardiogram (VCG). The orthogonal Frank leads were synthesized from the standard 12 lead ECG [5, 6].

Five parameters were obtained from the VCG with two different computation methods [7]:

- maximum angle between QRS and T loop axes
- T axis elevation and azimuth angle difference
- Ratio of maximum to mean T vector magnitudes
- Angle of the T-loop in frontal plane
- Angle of the T-loop in the horizontal plane.

2.1. T-loop parameters

The QRS and T axes are determined from the zero point of the VCG (the isoelectric point in ECG) to the most remote point of the respective loops, and the maximum angle MA is given by:

$$MA = \max(A_F, A_H, A_{LS})$$

where A_F, A_H and A_{LS} are the angles in the frontal, horizontal and left sagittal VCG planes.

The mean absolute difference between frontal plane elevation and azimuth angles (DEA) along the entire segment of repolarization is given by:

$$DEA=\text{mean}(\text{abs}(\alpha_n - \beta_n))$$

where α_n and β_n are the frontal plane Elevation and Azimuth angles of sample n.

The ratio of maximum to mean vector magnitudes (RMMV) is given by:

$$RMMV = \max(V_n)/\text{mean}(V_n),$$

and

$$V_n = \sqrt{V_{nX}^2 + V_{nY}^2 + V_{nZ}^2}$$

where V_n is the magnitude of the spatial vector of the T loop at sample n and V_{nX}, V_{nY} and V_{nZ} are the corresponding projections on the orthogonal axes.

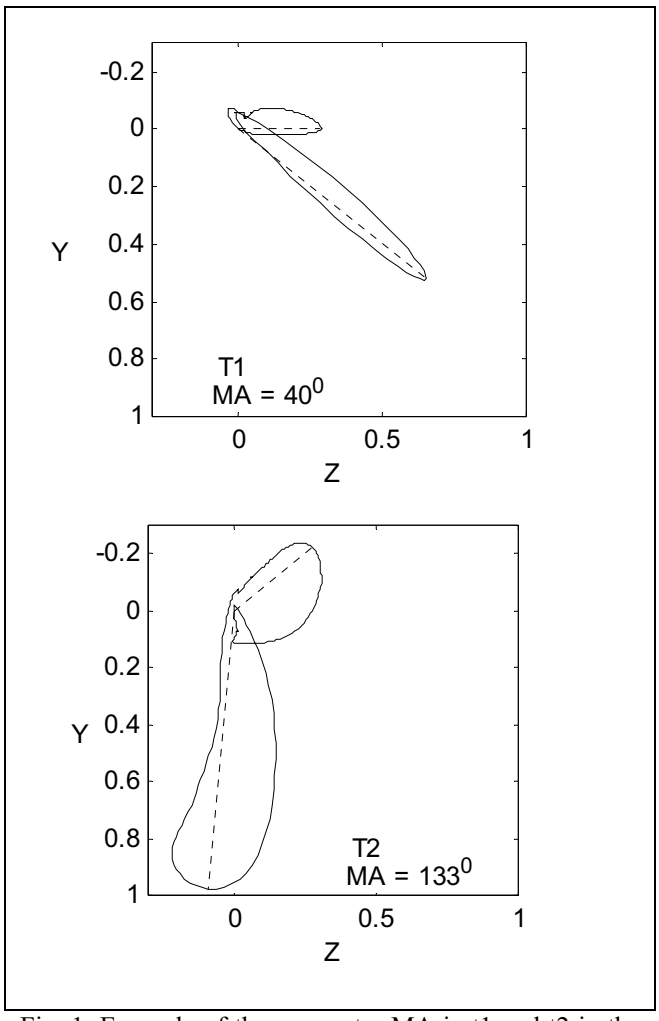

Fig. 1. Example of the parameter MA in t1 and t2 in the angina pectoris group.

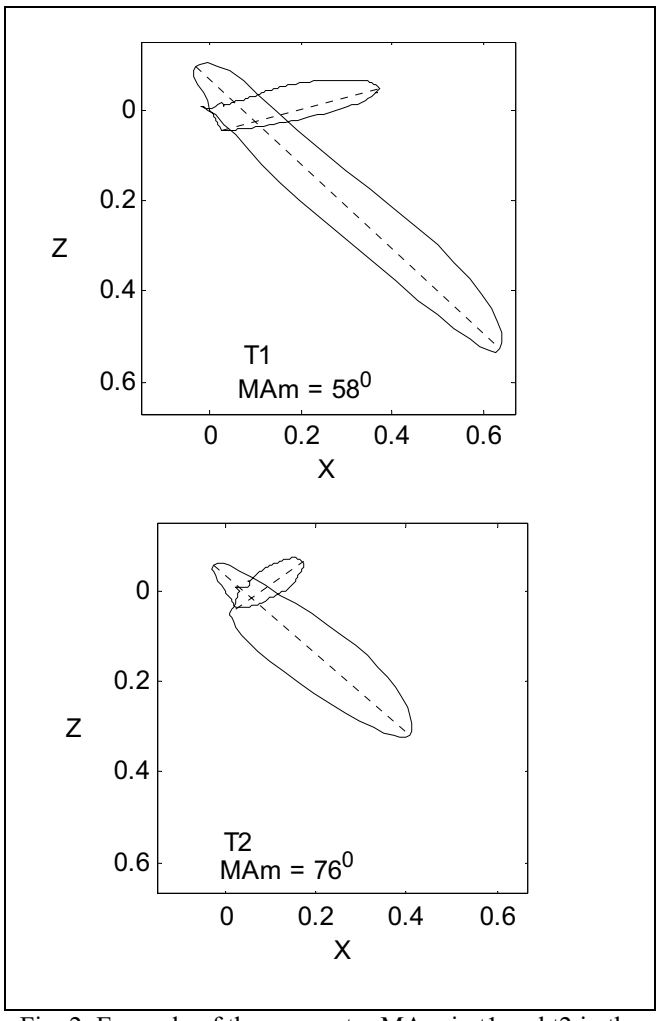

Fig. 2. Example of the parameter MAm in t1 and t2 in the healthy group.

In addition, the angle of the T-loop axis in the frontal (TF) and in the horizontal (TH) planes are considered [8].

The T loop parameter measurements with respect to the zero point of the VCG (the isoelectric point in the ECG) may be not very appropriate, for example when the zero point is not included in the T loop.

Considering that the size and direction of an ellipse (the form QRS and T loops mostly look like) is best characterized by its major axis, an alternative computation method was used. As described in [7], the two points of the loop with the maximum distance are detected and the point nearest to the zero point of the VCG loop is then considered (zero*) for the analysis. Then five modified parameters (MAm, DEAm, RMMVm ,TFm, THm) are measured with respect to the new considered zero* point.

2.2. Experimental data

The population based ECG-ILSA database (Italian Longitudinal Study on Aging) has been considered. This database is composed by 2513 ECG signals of elderly people (1337 males and 1176 females aged from 65 to 85 years old) [9-11].

This ECG-ILSA database consists of 2513 ECG signals in the first phase (t_1) and 1352 ECG signals in the second phase ($t2 = t_1 + 5$ years). In this study all the patients present both in t_1 and t2 have been considered. Both ECG are present in 901 patients (484 male and 417 female, with a mean age (in t_1) of 73.25 ± 5.5 years).

The following five groups have been selected for this study:

Table 1. Mean value ± standard deviation of the parameters MA, DEA, RMMV, TF, TH and MAm, DEAm, RMMVm, TFm, THm in t1 and t2 in the healthy group.

Parameter	t1	t2	t1-t2
MA	84.6±50.6	88.9±51.8	-4.33 ±39.4
DEA	61.0±18.7	59.9±18.6	1.05±18.8
RMMV	2.2±0.3	2.2±0.3	0.03±.43
TF	33.2±18.0	35.5±15.9	-2.3± 18.4
TH	-16.4±22.8	-22.4±28.8	6.0±19.3
MAm	88.7±55.1	93.1±54.0	4.3±45.7
DEAm	56.4±17.5	58.7±21.3	2.33±25.4
RMMVm	2.38±0.3	2.3±0.3	0.08±0.5
TFm	32.3±21.5	34.0±18.0	-1.7±22.2
THm	-14.8±26.9	-21.2±33.9	6.4±22.3

Table 2. Mean value ± standard deviation of the parameters MA, DEA, RMMV, TF, TH and MAm, DEAm, RMMVm, TFm, THm in t1 and t2 in the angina pectoris group.

Parameter	t1	t2	t1-t2
MA	83.2±52.7	100.8±54.7	-17.7±43.4
DEA	68.5±15.8	66.6±17.9	1.9±22.0
RMMV	2.1±0.5	2.0±0.4	0.1±.6
TF	38.1±13.7	14.3±66.2	23.8±64.9
TH	-13.7±37.8	-30.9±54.2	17.1±50.3
MAm	89.5±58.4	106.7±57.2	-17.3±55.5
DEAm	64.7±19.9	63.5±21.8	1.1±31.4
RMMVm	2.2±0.6	2.1±0.4	0.1±0.6
TFm	37.7±13.9	14.0±59.6	23.7±59.8
THm	-8.59±50.3	-31.9±58.3	23.4±57.8

- 147 healthy subjects
- 219 patients with only hypertension (Hypt)
- 77 patients with only cardiac diseases (Card)
- 44 patients with angina pectoris (AP)
- 51 patients with myocardial infarction (MI)

The first three groups are mutually exclusive, as the last two. In the AP group, there are no morphology modifications of the QRS complex from t1 to t2. The "healthy" group is characterized by absence of cardiovascular and chronic pulmonary diseases, by no use of drugs that can influence the electrical cardiac activity, and by no electrolyte imbalance [9].

3. Results and discussion

The 5 'original' parameters (MA, DEA, RMMV, TF, TH) and the 5 modified parameters (MAm, DEAm, RMMVm, TFm, THm) have been computed in the 5 groups of patients selected from the ECG-ILSA database. An example of the MA parameter in the Angina Pectoris group is shown in Fig. 1, while Fig. 2 reports MAm in the healthy group.

Table 1 reports the mean value and the standard deviation of the considered parameters in the healthy group, and Table 2 reports the corresponding results in the angina pectoris group.

Figure 3 reports the differences between the parameters MA in t1 and t2 sorted in increasing order in the healthy group.

In order to evaluate the longitudinal modifications from t1 to t2 of the considered parameters in the 5 groups, a paired t-test was performed, and the results are reported in Table 3.

Analysing this table, it is possible to observe a "stability" of the T-loop morphology measurements in a temporal interval of 5 years. In addition, the Angina Pectoris group, characterized by a high "clinical instability" showed the most significant longitudinal modifications of repolarization phase.

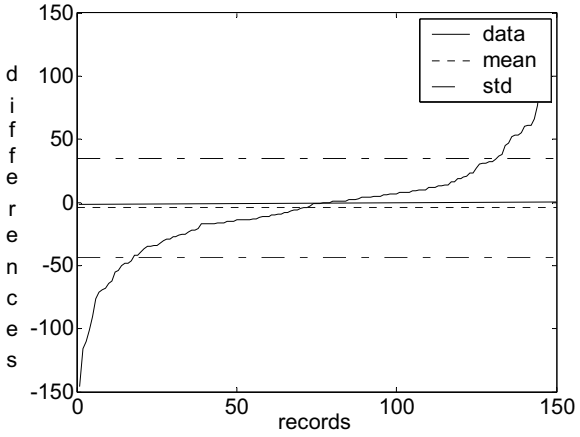

Fig. 3. Differences of MA(t1) – MA(t2) sorted in ascending order in the healthy group. The mean value ± standard deviation are reported.

Table 3. P values of the paired t-test of the parameters MA, DEA, RMMV, TF, TH and MAm, DEAm, RMMVm, TFm, THm in t1 and t2 considering the Healthy, Hypt, Card, AP and MI groups (s.l. 5%).

Parameter	Healthy	Hytp	Card	AP	MI
MA	n.s.	n.s.	n.s.	<0.01	n.s.
DEA	n.s.	n.s.	n.s.	n.s.	n.s.
RMMV	n.s.	n.s.	n.s.	n.s.	n.s.
TF	n.s.	n.s.	n.s.	0.019	n.s.
TH	<0.01	n.s.	n.s.	0.028	n.s.
Mam	n.s.	n.s.	n.s.	0.044	n.s.
DEAm	n.s.	n.s.	n.s.	n.s.	n.s.
RMMVm	n.s.	0.031	n.s.	n.s.	n.s.
TFm	n.s.	n.s.	n.s.	0.011	n.s.
THm	<0.01	n.s.	n.s.	0.010	n.s.

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