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Review on the Diagnostic Potentials of the T-loop Morphology in VCG

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Abstract: In the present work, the characterization and quantification of heterogeneous cardiac repolarization have been considered, and different studies of the authors considering particular aspects of the T-loop morphology have been reviewed. In particular, the longitudinal modifications, the age and gender influences and the diagnostic relations have been reported. The population based ECG-ILSA (Italian Longitudinal Study on Aging) database has been used in all studies. The orthogonal Frank leads were synthesized from the standard 12 lead electrocardiogram. Depending on the different studies, six to ten parameters have been obtained from the vectorcardiograms with two different methods of considering the zero point. The resulting conclusions were:

1. The modified parameters calculated towards the major axis of the T-loop proved to yield higher discriminative power.
2. The mean values of all parameters of the T-loop morphology of the healthy subjects group are statistically different from those of ischemia or myocardial infarction groups.
3. Stability of the T-loop morphology measurements made in a temporal interval of 5 years (longitudinal modifications) for one and the same patient is observed. The Angina Pectoris group characterized in general by a high "clinical instability" shows the most significant longitudinal modifications.
4. Age (< 75 years and ≥ 75 years old) and gender (male/female) have different T-loop morphology impact in the three considered groups (healthy, cardiac diseases, and hypertension). The gender influences the healthy and patients with hypertension, while age influences mainly the patients with cardiac diseases.

Keywords: Electrocardiography ECG, Vectorcardiography VCG, T-loop morphology.

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1. INTRODUCTION

Several publications aroused the interest in T-wave morphology. Lemire et al. [17] assert that information concerning myocardial ischemia can be obtained from the time-frequency representation of the T-wave morphology. Kors et al. [15] investigate the QT dispersion as an attribute of the T-loop morphology, observing that small and wide T loops produce larger QT dispersion compared to large and narrow ('normal') loops. Kallert et al. [14] assess the heterogeneous repolarization by quantitative parameters describing the T wave loop shape and subtle changes in its course. Nowinski et al. [20] are reporting for changes in ventricular repolarization during percutaneous transluminal coronary angioplasty in humans, observing that T loop morphology is more sensitive to coronary occlusion than QT dispersion.

Estimation of the T loop axis in relation to the QRS complex axis has long been recognized. It yields adequate information for detection of myocardial infarction and ischemia and their location in the myocardium. While the infarction is mostly connected with the QRS loop morphology and axes direction, the ischemia of the myocardium impairs its recovery process. When a portion of the ventricular wall is so affected, the normal sequence of ventricular repolarization will be disturbed and the resultant potential altered. Consequently, abnormalities are manifested in the T vectors [12].

It was shown that the T wave loop axis is a strong and independent risk indicator for fatal and non-fatal cardiac events in the elderly [16]. In addition, the vector deviation between the depolarization and repolarization waves was introduced in this context [1].

The diagnostic potentials of the T wave have been investigated in series of publication of our team. Visible changes in the T (or T-U) wave of the sinus beat immediately following a ventricular premature beat are not infrequently observed in electrocardiograms of both healthy subjects and cardiac patients. Batchvarov et al. [2] hypothesize that ventricular repolarization of the 1st sinus complex is modulated even in the absence of visible to the naked eye T wave changes. Although the vectorcardiogram (VCG) contains the same information as the scalar electrocardiogram (ECG), its specific form of presentation allows the detection of abnormalities that are not

immediately visible on the scalar ECG. Analyzing quantitatively the T-loop of the VCG, the authors are declaring that the postextrasystolic repolarization modulation is very likely more frequent than previously appreciated, and therefore deserves further studies in both healthy subjects and patients with various cardiac diseases.

T wave alternans (TWA) is an electrophysiological phenomenon associated with a risk factor of sudden cardiac death. Bortolan and Christov [8] suggested a method for detection and quantification of TWA by T wave amplitude statistical analysis and Principal Component Analysis (PCA). This method achieved 1st prize at the PhysioNet/Computers in Cardiology Challenge, 2008. The method was applied searching for QRS and T wave alternans and beat-to-beat ventricular repolarization variability in patients with suspected Brugada syndrome [9]. Patients with positive ajmaline test (i.e. likely carriers of mutations for Brugada syndrome) have increased beat-to-beat ST-T wave variability compared to those with negative tests. Importantly, this variability does not follow 2:1 pattern and cannot be detected by amplitude measurements, which form the basis for most current algorithms for detection of 2:1 microvolt TWA. It was shown that patients with positive ajmaline tests also had increased 2:1 QRS alternans. The conclusion of the study is that the diagnosis of Brugada syndrome is likely to be improved by analysis of ST-T variability and 2:1 QRS alternans.

The current material is an effort to summarize part of the series of publications, done by us during the years, about the diagnostic potentials of the T-loop morphology. We will focus on T-loop morphology characterization of myocardial infarction and ischemia [5], on the longitudinal modifications in a temporal interval of 5 years [6], and also on the gender and age influences in T-loop morphology [7].

2. MATERIALS AND METHODS

Particular aspects of T-wave morphology are considered for characterization and quantification of heterogeneous repolarization, using the VCG. Several methods for synthesizing Frank VCGs from simultaneously recorded 12 standard leads have been investigated

and analyzed [21]. Levkov's derivation of the orthogonal leads [13, 18] has been used in this study.

Five parameters were obtained from the VCG [5-7]:

- maximum angle between QRS and T loop axes (MA),
- T axis elevation and azimuth angle difference (DEA),
- Ratio of maximum to mean T vector magnitudes (RMMV),
- Angle of the T-loop in frontal plane (TF)
- Angle of the T-loop in the horizontal plane (TH).

Maximum angle between QRS and T loop axes

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. For example, the angle between the T and QRS loop axes in the frontal plane of Fig. 1, where the corresponding axes are determined from the zero point of the VCG to a point of the loop with maximum length, gives a value of An = 28^0

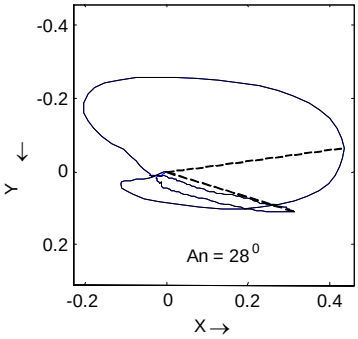

Fig. 1. Angle between the QRS and T loop axes in the frontal plane

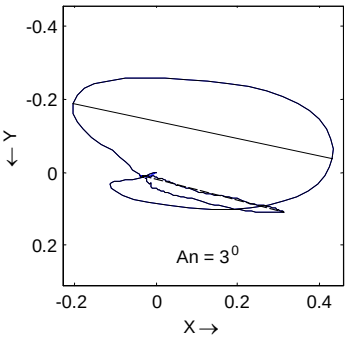

Fig. 2. The QRS and T loops from Fig.1. An = 3^0 between the major axes of the loops

The angles (A_F, A_H and A_{LS}) in the three VCG planes – frontal, horizontal and left sagittal – are computed, and the maximum value is the considered parameter MA:

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

The estimation of the T loop axis in relation to the QRS complex axis provides adequate information for detection of myocardial infarction and ischemia and their location in the myocardium. The

orientation of QRS and T loops are close to each other in normal case, whereas they are far from each other in some heart diseases [1].

T axis elevation and azimuth angles difference
The difference between frontal plane elevation and azimuth angles (DEA) is calculated along the entire segment of repolarization, providing a description of the T-wave loop morphology [14]. DEA is defined as the mean absolute value of the difference between the frontal plane Elevation (α) and Azimuth (β) of all loop samples (n).

$$DEA = mean(abs(\alpha_n - \beta_n))$$

The Elevation with respect to the frontal plane is the angle between the loop axis at sample *n* and the Z axis in the left sagittal plane, while the Azimuth is the angle between the loop axis at the same sample and the X axis in the frontal plane (Fig. 2).

Ratio of maximum to mean T vector magnitudes
The ratio of maximum to mean vector magnitudes (RMMV) is adopted from the work of Kallert et al. [14]:

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

where V_n is the magnitude of the spatial vector of the T loop at sample n (Fig. 2).

The magnitude is calculated by the Pythagorean formula:

$$V = \sqrt{V_X^2 + V_Y^2 + V_Z^2}$$

where V_X, V_Y and V_Z are the magnitudes of the projection of the spatial vector on the orthogonal axes.

Angles of the T-loop in frontal plane and in horizontal plane
The idea that the angles of the T-loop in frontal (TF) and in horizontal plane (TH) are diagnostically worthwhile is adopted from the work of Kors et al. [16]

Modified parameters
The ST segment elevation in the electrocardiogram leads is a recognized reliable indicator of myocardial injury, ischemia or infarction. For this reason, T loop parameter measurements with

respect to the zero point of the VCG (the isoelectric point in the ECG) may lead to errors. This is especially valid when the zero point is not included in the T loop (see the left sagittal plane of Fig. 3).

The size and direction of an ellipse (the form QRS and T loops mostly look like) is best characterized by its major axis. Such an approach is found in Nowinski et al. [20], where T loop Eigen values parameter is defined as a ratio of the major to the minor axis of the ellipse.

In order to capture the information of major axes, 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 (called zero*) for the following analysis. Then three modified parameters (MAm, DEAm, RMMVm) are measured with respect to the new considered zero* point.

The difference between the two measurement techniques is illustrated in Fig. 2. The angle between the QRS and T loops of Fig. 1 changed from An=28^{o} to the 'modified' value An=3^{0}.

Some component of the DEAm and RMMVm parameter measurements with respect to the new reference point (zero*) are shown in Fig. 3.

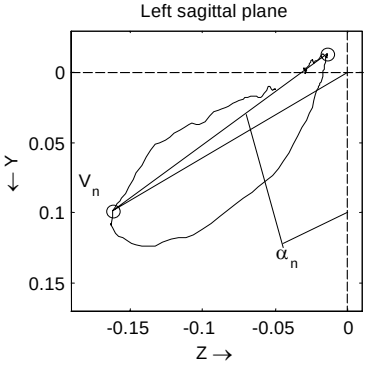

Fig. 3. DEAm and RMMVm parameter measurements with respect to the point of the major axis nearest to the zero VCG point

Statistical analysis

In the comparisons between two subgroups, the differences have been tested by the parametric Student's unpaired t-test and in temporal comparisons by paired t-test. It was considered the significance level (s.l.) of 5% in all tests.

3. EXPERIMENTAL DATA AND RESULTS

The population based ECG-ILSA database (Italian Longitudinal Study on Aging) has been considered. This database is composed by 2513 ECG signals of old people (1337 males and 1176 females aged from 65 to 85 years old) [7, 8, 19].

Ischemia or myocardial infarction study
The following four groups have been selected for this study:
328 healthy subjects
123 patients with ischemia (ISCH)
172 patients with myocardial infarction (MI)
59 patients with ischemia & myocardial infarction (ISCH&MI)

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 [11]. In the remaining three groups, additional diseases (hypertension, diabetes, etc.) may be present.

The 3 'original' parameters (MA, DEA, RMMV) and the 3 modified parameters (MAm, DEAm, RMMVm) have been computed in the 4 groups of patients.

The mean values and the standard deviation of the 6 parameters in the group of healthy patients are reported in Table 1. Table 2 reports the corresponding values in the group of patients with ischemia, myocardial infarction or both. Cross-comparison between healthy and the other groups performed with t-test for all the parameters is shown in Table 3.

Table 1. Mean±SD of MA, DEA, RMMV and MAm, DEAm, RMMVm in the: healthy group.

Parameter	Healthy
MA	78.95 ± 52.24
DEA	59.29 ± 17.02
RMMV	2.18 ± 0.32
MAm	82.10 ± 55.02
DEAm	56.72 ± 19.31
RMMVm	2.36 ± 0.31

Table 2. Mean±SD of MA, DEA, RMMV and MAm, DEAm, RMMVm in the three groups: ISCH, MI, ISCH&MI.

Parameter	ISCH	MI	ISCH&MI
MA	91.67 ± 52.73	113.13 ± 50.28	118.42 ± 51.68
DEA	61.80 ± 17.94	62.28 ± 17.73	64.85 ± 18.22
RMMV	2.05 ± 0.41	2.01 ± 0.39	2.02 ± 0.42
MAm	99.89 ± 57.00	118.22 ± 50.49	125.81 ± 53.38
DEAm	64.88 ± 21.36	62.84 ± 26.31	70.78 ± 29.10
RMMVm	2.15 ± 0.46	2.11 ± 0.38	2.10 ± 0.40

Table 3. Cross-comparison (t-test) between healthy vs patients with Ischemia, Myocardial Infarction and both (significance level 5%).

Parameter	Healthy vs ISCH	Healthy vs MI	Healthy vs ISCH&MI
MA	-	p<0.0001	p<0.0001
DEA	-	-	-
RMMV	p=0.0004	p<0.0001	p=0.0007
MAm	p=0.0026	p<0.0001	p<0.0001
DEAm	p=0.0001	p=0.0032	p<0.0001
RMMVm	p<0.0001	p<0.0001	p<0.0001

From this statistical analysis it comes out that the mean values of the three modified parameters of the healthy subjects group are statistically different from those of ischemia or myocardial infarction groups. In addition, the modified parameters proved to yield higher discriminative power.

Longitudinal modifications study

For the study of temporal modifications of the T-loop morphology, all the patients of the ILSA database with ECG recordings both in the first baseline phase (at time t1), and in the second follow-up phase (at time t2=t1+5 years) have been considered. This group of patients consists of 901 individuals (484 males, 417 females, mean age 73.25±5.5 years in t1). The following 5 sub-groups have been selected for this study:

147 healthy individuals;
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 characterised 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 [11].

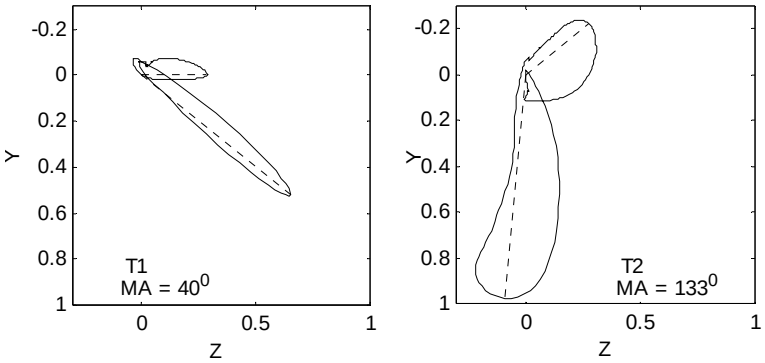

Fig. 4. Example of the parameter MA in t1 and t2 in the angina pectoris group

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. An example of the MA parameter in the Angina Pectoris group is shown in Fig. 4, while Fig. 5 reports MAm in the healthy group.

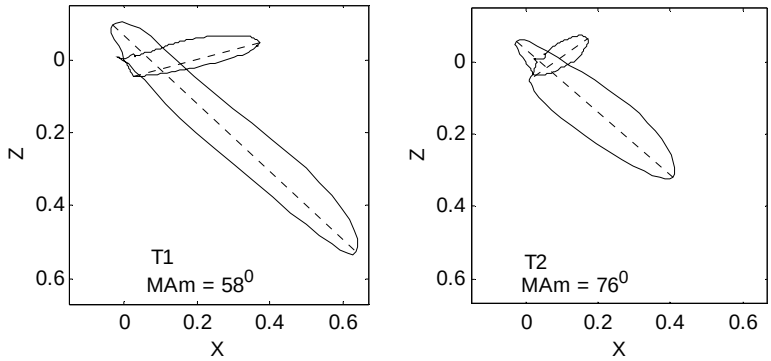

Fig. 5. Example of the parameter MAm in t1 and t2 in healthy group

Table 4 reports the mean value and the standard deviation of the considered parameters in the healthy group, and Table 5 reports the corresponding results in the angina pectoris group.

Table 4. Mean±SD of 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 5. Mean±SD 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

Figure 6 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 6.

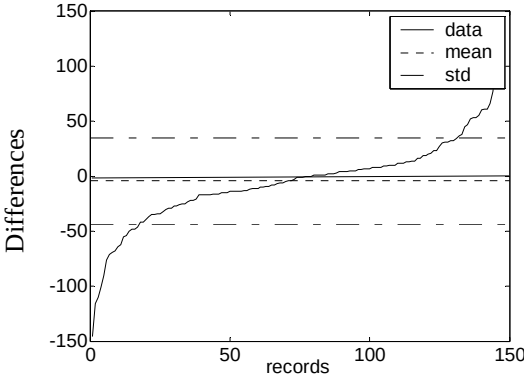

Fig. 6. Differences of MA(t1) – MA(t2) sorted in ascending order in the healthy group. The mean value ± standard deviation are reported.

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

Table 6. 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	Hypt	Card	AP	MI
MA	-	-	-	<0.01	-
DEA	-	-	-	-	-
RMMV	-	-	-	-	-
TF	-	-	-	0.019	-
TH	<0.01	-	-	0.028	-
Mam	-	-	-	0.044	-
DEAm	-	-	-	-	-
RMMVm	-	0.031	-	-	-
TFm	-	-	-	0.011	-
THm	<0.01	-	-	0.010	-

Age and gender study

For studying the age and gender influences, the following three groups have been selected from the entire ECG-ILSA database:

- 328 healthy subjects
- 643 patients with only hypertension (HYPT)
- 172 patients with only cardiac diseases (CARD)

Table 7. Mean±SD of MA, DEA, RMMV, TF, TH and MAm, DEAm, RMMVm, TFm, THm in Male and Female in the Healthy group and p value of t-test (s.l. 5%).

Parameter	M	F	p
MA	87.8 ± 52.3	67.3 ± 50.0	p<0.001
DEA	62.7 ± 17.0	54.8 ± 16.0	p< 0.001
RMMV	2.2 ± 0.3	2.2 ± 0.3	-
TF	33.9 ± 17.3	38.6 ± 13.2	p<0.01
TH	-23.5 ± 24.0	-8.9 ± 17.9	p<0.001
MAm	91.6 ± 55.5	69.5 ± 52.0	p<0.001
DEAm	57.2 ± 18.5	56.1 ± 20.4	-
RMMVm	2.4 ± 0.3	2.4 ± 0.3	-
TFm	33.0 ± 19.3	37.8 ± 15.4	p=0.017
THm	-21.6 ± 27.8	-5.6 ± 22.6	p<0.001

Table 8. Mean±SD of the MA, DEA, RMMV, TF, TH and MAm, DEAm, RMMVm, TFm, THm in M and F in the CARD group and p value of t-test (s.l. 5%).

Parameter	M	F	p
MA	100.9 ± 52.4	92.1 ± 54.9	-
DEA	62.3 ± 1.8	60.3 ± 20.1	-
RMMV	2.1 ± 0.4	2.1 ± 0.5	-
TF	25.1 ± 53.4	30.6 ± 50.7	-
TH	-30.9 ± 48.9	-26.3 ± 45.1	-
MAm	106.7 ± 57.4	97.6 ± 59.7	-
DEAm	58.4 ± 23.6	64.8 ± 22.6	-
RMMVm	2.2 ± 0.4	2.2 ± 0.5	-
TFm	22.8 ± 57.5	25.3 ± 51.8	-
THm	-29.3 ± 54.7	-20.1 ± 56.8	-

The three groups are mutually exclusive. 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 [11]. In addition to the two gender groups, two age groups have been established (<75 years and ≥ 75 years old).

The 5 'original' parameters (MA, DEA, RMMV, TF, TH) and the 5 modified parameters (MAm, DEAm, RMMVm, TFm, THm) have

been computed in the 3 groups of patients selected from the ECG-ILSA database.

Table 9. Mean±SD of MA, DEA, RMMV, TF, TH and MAm, DEAm, RMMVm, TFm, THm in M and F in the HYPT group and p value of t-test (s.l. 5%).

Parameter	M	F	p
MA	96.2 ± 52.2	82.9 ± 51.3	p<0.001
DEA	62.1 ± 15.1	57.2 ± 19.5	p<0.001
RMMV	2.2 ± 0.3	2.1 ± 0.4	p=0.022
TF	32.4 ± 28.5	38.2 ± 35.1	p=0.024
TH	-23.0 ± 29.4	-13.0 ± 37.6	p<0.001
MAm	102.1 ± 55.3	84.9 ± 55.4	p<0.001
DEAm	59.9 ± 19.9	57.6 ± 21.2	-
RMMVm	2.3 ± 0.3	2.3 ± 0.4	-
TFm	31.1 ± 32.9	35.9 ± 37.4	-
THm	-22.9 ± 34.7	-9.1 ± 40.5	p<0.001

Table 10. Mean±SD of MA, DEA, RMMV, TF, TH and MAm, DEAm, RMMVm, TFm, THm in <75 and ≥75 in the Healthy group and p value of t-test (s.l. 5%).

Parameter	<75	≥75	p
MA	78.4 ± 51.8	80.1 ± 53.3	-
DEA	58.8 ± 17.4	60.2 ± 16.3	-
RMMV	2.2 ± 0.3	2.2 ± 0.3	-
TF	35.7 ± 15.0	36.4 ± 17.5	-
TH	-17.5 ± 24.1	-16.5 ± 19.6	-
MAm	80.0 ± 54.6	86.4 ± 55.8	-
DEAm	56.2 ± 18.9	57.7 ± 20.2	-
RMMVm	2.3 ± 0.3	2.4 ± 0.3	-
TFm	34.8 ± 16.0	35.5 ± 21.2	-
THm	-15.0 ± 28.7	-14.1 ± 22.5	-

First, the gender influence has been investigated. Table 7 reports the mean value and the standard deviation of the considered parameters in Male and Female in the healthy group and the p-value of the t-test. Table 8 and Table 9 report respectively the corresponding results in the CARD and HYPT groups.

Analysing these tables, it can be observed that gender influences only the healthy and the HYPT groups. For example, the MA index

in the healthy group shows the values of 87.8 ± 52.3 in male and 67.3 ± 50.0 in female (p<0,001); in the hypertension group 96.2 ± 52.2 in M and 82.7 ± 51.3 in F (p=0,001), while in patients with cardiac disease no significant differences were observed. The remaining 9 parameters show "substantially" a similar behaviour.

Table 11. Mean±SD of MA, DEA, RMMV, TF, TH and MAm, DEAm, RMMVm, TFm, THm in <75 and ≥75 in the CARD group and p value of t-test (s.l. 5%).

Parameter	<75	≥75	p
MA	88.0 ± 51.4	109.5 ± 53.6	p<0.01
DEA	61.6 ± 18.2	61.6 ± 20.5	-
RMMV	2.1 ± 0.4	2.1 ± 0.5	-
TF	27.9 ± 47.7	26.2 ± 57.8	-
TH	-22.9 ± 44.7	-36.9 ± 49.8	-
MAm	90.4 ± 56.6	119.3 ± 56.6	p=0.001
DEAm	60.0 ± 21.2	61.8 ± 26.0	-
RMMVm	2.2 ± 0.4	2.2 ± 0.5	-
TFm	26.1 ± 51.8	20.7 ± 59.6	-
THm	-19.7 ± 51.1	-33.4 ± 60.0	-

Table 12. Mean±SD of MA, DEA, RMMV, TF, TH and MAm, DEAm, RMMVm, TFm, THm in <75 and ≥75 in the HYPT group and p value of t-test (s.l. 5%).

Parameter	<75	≥75	p
MA	87.9 ± 51.5	90.3 ± 53.2	-
DEA	59.4 ± 17.3	59.4 ± 18.8	-
RMMV	2.1 ± 0.4	2.1 ± 0.3	-
TF	35.4 ± 29.2	36.1 ± 38.0	-
TH	-15.3 ± 33.3	-21.4 ± 36.4	p=0.031
MAm	92.1 ± 55.5	93.2 ± 57.0	-
DEAm	59.2 ± 20.5	57.5 ± 20.9	-
RMMVm	2.3 ± 0.4	2.3 ± 0.3	-
TFm	34.2 ± 32.1	32.9 ± 41.4	-
THm	-13.2 ± 36.9	-18.9 ± 41.6	-

The subsequent analysis consider the two age subgroups (<75 years and ≥ 75 years old). Table 10 reports the mean value and the standard deviation of the considered parameters in <75 and ≥ 75 in the healthy group and the p-value of the t-test. Table 11 and Table 12

report respectively the corresponding results in the CARD and HYPT groups.

Considering the MA index in the two age subgroups, the following results were respectively observed: no significant differences in the healthy group and in the hypertension group, while 88.0 ± 51.4 (<75 years old) and 109.5 ± 53.6 (≥ 75 years old) in patients with cardiac diseases ($p<0.01$).

CONCLUSIONS

1. The modified parameters calculated towards the major axis of the T-loop proved to yield higher discriminative power.
2. The mean values of all parameters of the T-loop morphology of the healthy subjects group are statistically different from those of ischemia or myocardial infarction groups.
3. Stability of the T-loop morphology measurements made in a temporal interval of 5 years (longitudinal modifications) for one and the same patient is observed. The Angina Pectoris group characterized in general by a high "clinical instability" shows the most significant longitudinal modifications.
4. Age (< 75 years and ≥ 75 years old) and gender (male/female) have different T-loop morphology impact in the three considered groups (healthy, cardiac diseases, and hypertension). The gender influences the healthy and patients with hypertension, while age influences mainly the patients with cardiac diseases.

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