Gender Related Modification in ECG and VCG in Elderly People

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Abstract

***Objective**: Objective of the current study is to investigate the effect of cardiovascular diseases and diabetes mellitus on modifications in electrocardiographic (ECG) and vectorcardiographic (VCG) features, considering an elderly population, most of them with multiple comorbidities.*

***Materials**. Italian Longitudinal Study on Aging (ILSA-CNR) database was created to evaluate physiologic and pathologic modifications connected with aging. Standard 12-leads ECG recordings (10 sec, 500 Hz) were taken with a follow-up of three years. The study examined 1109 males and 918 females aged 65-84 years. All considered parameters were 21: 10 from ECG signal, 10 from VCG signal and Heart Rate (HR).*

***Results and Discussion**. Groups with different heart diseases (Diabetes, Angina, Hypertension, Myocardial Infarction and Arrhythmia) are compared to the Healthy group. Only five parameters (T-wave area dispersion, T-ratio, T-roundness, T-PCA and T amplitude) all related to T-wave, presented statistically significant differences both for males and females between Healthy and heart diseases group. For QRS related parameters there is different behavior between males and females. Myocardial Infarction, Arrhythmia, and Heart Failure are the diseases with greatest impact on the ECG and VCG parameters.*

1. Introduction

Electrocardiographic (ECG) and vectorcardiographic (VCG) morphological abnormalities have been used for long in detection of cardiovascular diseases and prediction of the risk for sudden cardiac death. Some parameters as ST-segment elevation, QRS-complex duration, QT dispersion, T-wave area dispersion, spatial QRS-T angle, etc. have established clinical significance.

For example, measurements and analysis of ST-elevation were studied as a risk factor in different groups of hemodialysis patients [1, 2].

A prolonged QRS duration was an independent predictor of increased total mortality or sudden death [3, 4].

QT interval dispersion (QTd) reflects the inhomogeneity of electrical activity in different segments of left ventricle, and several studies showed an increase of QT dispersion in various cardiac diseases [5, 6].

In addition, normal aging is associated with several functional and structural changes in the cardiovascular system, and heart aging is manifested in increased heart's mass and fibrosis of the conduction system. [7, 8], and in elderly people, the occurrence of widespread histologic changes in the conduction system may alter several features of the electrocardiogram.

In a previous study [7] serial ECG recordings in elderly people were examined and an age-related ECG attenuation (QRS- and T-waves) was found in males, but not in females. This finding was not associated with any specific cardiovascular disease, and was also present in the healthy subgroup.

Objective of the current study is to investigate gender-related effects of cardiovascular diseases and diabetes mellitus on modifications in ECG and VCG features, considering an elderly population. The population based sample examined was characterized by multiple comorbidities.

2. Materials

This study considers a subset of an ECG database developed in the framework of Italian Longitudinal Study on Aging project (ILSA-CNR). This database was created to evaluate physiologic and pathologic modifications connected with aging [9].

Standard 12-leads ECG recordings (10 sec, 500 Hz) were taken at baseline and after three years. The database consisted of a random sample of individuals aged 65-84 years, living independently or in institutions, stratified by age and sex using the equal allocation strategy, identified on the demographic list of the registry office of eight Italian municipalities.

Table 1 Distribution of the male population (n=1109) in the groups of: Healthy, Diabetes Mellitus, Angina Pectoris, Hypertension, Myocardial Infarction, Arrhythmia, Congestive Heart Failure.

	Healty	Diab.M	AnginaP.	Hypert	Myoc.Inf	Arrhyt	C.Hrt.Flr
Healty	**219**	0	0	0	0	0	0
Diab.M	0	**130**	14	96	28	57	10
Angina P.	0	14	**99**	69	41	41	15
Hypert	0	96	69	**607**	99	252	50
Myoc.Inf	0	28	41	99	**160**	72	28
Arrhyt	0	57	41	252	72	**386**	47
C.Hrt.Flr	0	10	15	50	28	47	**73**

Table 2. Distribution of the female population (n=918) in the groups of: Healthy, Diabetes Mellitus, Angina Pectoris, Hypertension, Myocardial Infarction, Arrhythmia, Congestive Heart Failure

	Healty	Diab.M	Angina P.	Hypert	Myoc.Inf	Arrhyt	C.Hrt.Flr
Healty	**161**	0	0	0	0	0	0
Diab.M	0	**136**	18	117	14	51	28
Angina P.	0	18	**79**	67	18	36	16
Hypert	0	117	67	**648**	49	194	75
Myoc.Inf	0	14	18	49	**66**	22	16
Arrhyt	0	51	36	194	22	**262**	47
C.Hrt.Flr	0	28	16	75	16	47	**95**

The following diagnostic groups have been considered for the analysis:

- Patients with a history of cardiovascular disease: arrhythmia (ARRH), angina pectoris (AP), myocardial infarction (MI), congestive heart failure (CHF), hypertension (HYPT).
- Patients with diabetes mellitus DM
- Healthy subjects, characterized by the absence of any cardiovascular, neurological, chronic pulmonary disease or diabetes, by the absence of therapy potentially influencing cardiac electrical activity, and by the absence of electrolyte imbalance.

A group of 1109 males and 918 females was involved in the study, and their composition are reported in Table 1 (Male) and Table 2 (Female).

3. Methods

The ECG signals were preprocessed to eliminate or suppress the powerline interference [11], the drift of the baseline [12] and the electromyographic noise [13].

For this study, 21 parameters were considered: 10 from ECG signal, 10 from VCG and the Heart Rate (HR). All ECG/VCG parameters were automatically measured, assuring the repeatability of the results.

The ten considered **ECG parameters** are the following: QRS-amplitude, QRS-PCA, QRS duration, QT-interval duration, T duration, QT-dispersion, ST-elevation, T-amplitude, T-PCA, T-area dispersion.

For example, the QRS-PCA and T-PCA are morphology parameters based on all 12 ECG leads. They are computed by Principle Component Analysis (PCA) through singular value decomposition, applied to QRS and T-wave intervals of all leads. They are defined as the ratio between the second and the first Eigen values (complexity index):

QRS_PCA: $\lambda_{2(QRS)} / \lambda_{1(QRS)}$

T_PCA: $\lambda_{2(T)} / \lambda_{1(T)}$

The T-area dispersion TWAD [14], was calculated as the average of normalized T-wave areas in specific standard leads, and it is defined by:

$$TWAD = \frac{1}{N}\sum_{i=1}^{N}\frac{Area_i}{\max(|Area_{i:N}|)}, \quad i \in \{I, II, V_4, V_5, V_6\}$$

TWAD was calculated from leads {I, II, V4, V5, V6}, because T waves in these leads were normally positive, and inversions in them conveyed prognostic value.

The 10 **VCG parameters** were the following: QRS-area, maximal QRS vector, QRS-angle, QRS-roundness index, T-area, maximal T-vector, T-angle, QRS/T-angle, T-vector ratio, and T- roundness index. Orthogonal Frank X, Y and Z leads were derived from the standard 12-leads, using the transfer matrix of Dower, 1968 [15]. Several vectorcardiographic 3-D and frontal plane 2-D parameters were measured such as: maximal vector of QRS- and T-loops, area of the loops, angles of the maximal vectors.

Another parameter, characterizing the roundness (circularity) of the loop, was the roundness index (RI) for QRS and T waves, measured as the ratio of the area of the QRS or T loop to the square of the corresponding

maximum vector [16]:

QRS_RI =QRS_Area/Vmax^2

T_RI =T_Area/Vmax^2

The T-loop vector ratio (VR_T) is defined by

$VR_T = \max(V_n) / \text{mean}(V_n)$ for { n } in T loop

where Vn is given by:

$$V_n = \sqrt{X_n^2 + Y_n^2 + Z_n^2}$$

The parameters of the considered groups were described by descriptive statistics (mean and standard deviation) and by the limits of the 95% confidence interval.

Nonparametric

Wilcoxon rank sum test (for equality of population medians) was used for testing the statistical significance of the comparisons between healthy vs groups with cardiac diseases and diabetics. All statistical analysis and data visualization were performed with Matlab R2019b.

4. Results and Discussion

All the electrocardiographic features were analysed considering the 7 diagnostic groups of the ILSA Database. A statistical analysis of the considered parameters was performed for all the 7 diagnostic groups. The mean values, the standard deviation and the 95% confidence interval were analyzed and studied, and Table 3 reports an example for the male population considering the QRS and T wave amplitudes in the Healthy, DM, HYPT and MI groups, while the same parameters and diagnostic groups are reported in Table 4 for the Female population. Comparison between the healthy group and all the other diagnostic groups was performed in order to test and to quantify their influence on the ECG and VCG parameters.

In particular, the ECG and VCG parameters of the healthy control group (n=219M, 161F) were compared with respect to the other groups: Diabetics DM (n=130M, 136F), Angina Pectoris AP (n=99M, 79F), Hypertension HYPT (n=607M, 648F), Myocardial Infarction MI (n=160M, 66F), Arrhythmia ARRH (n=386M, 262F), Congestive Heart Failure CHF (n=73M, 95F). Comorbid patients with different cardiovascular diseases (see Table 1 and Table 2) were examined more than ones in the corresponding groups.

Table 5, Table 6 and Table 7 reports the comparison of the Healthy group with respect to DM, AP, HYPT, MI ARRH and CHF considering different parameters for male and Females.

Only five parameters (T-wave area dispersion, T-ratio, T-roundness, T-PCA and T amplitude) all related to T-wave, presented statistically significant differences both for males and females between Healthy and heart diseases group. For QRS related parameters there is a different behavior between males and females. Myocardial Infarction, Arrhythmia, and Congestive Heart Failure are the diseases with greatest impact on the ECG and VCG parameters.

Table 3. Mean values (standard deviation) and 95% confidence interval of QRS and T wave amplitudes in males for DM, HYPT, MI and the healthy control group

	QRS amplitude	T amplitude
Healty	0.82 (0.31) [0.78; 0.86]	0.14 (0.08) [0.13; 0.15]
DM	0.83 (0.39) [0.76; 0.90]	0.08 (0.07) [0.07; 0.10]
HYPT	0.90 (0.38) [0.87; 0.93]	0.11 (0.09) [0.10; 0.11]
MI	0.76 (0.33) [0.71; 0.82]	0.08 (0.07) [0.07; 0.09]

Table 4. Mean values (standard deviation) and 95% confidence interval of QRS and T wave amplitudes in females for DM, HYPT, MI and the healthy control group

	QRS amplitude	T amplitude
Healty	0.71 (0.26) [0.67; 0.75]	0.11 (0.08) [0.10; 0.12]
DM	0.73 (0.31) [0.68; 0.78]	0.07 (0.06) [0.06; 0.08]]
HYPT	0.81 (0.33) [0.78; 0.83]	0.09 (0.07) [0.08; 0.09]
MI	0.76 (0.30) [0.69; 0.83]	0.07 (0.06) [0.06; 0.09

Table 5. Comparison of Healty group vs DM, AP, HYPT, MI, ARRH, CHF considering 4 ECG parameters related to QRS wave.

		QRS ampl	QRS angle	QRS vector	QRS area
DM	m	ns	ns	ns	ns
	f	ns	p<0.01	ns	p<0.01
AP	m	ns	ns	ns	p<0.01
	f	ns	ns	ns	ns
HYPT	m	p<0.01	ns	ns	p<0.01
	f	p<0.01	ns	p<0.01	p<0.01
MI	m	ns	ns	p<0.01	p<0.01
	f	ns	p=0.02	ns	ns
ARRH	m	ns	ns	ns	p<0.01
	f	p<0.01	p<0.01	ns	p<0.01
CHF	m	ns	ns	ns	ns
	f	p<0.01	p<0.01	ns	p<0.01

Table 6. Comparison of Healty group vs DM, AP, HYPT, MI, ARRH, CHF considering 4 ECG parameters related to QRS-T wave.

		QRS round	ST elevatl	QRS/T angle	T ampl
DM	m	ns	ns	ns	p<0.01
	f	ns	ns	ns	p<0.01
AP	m	p<0.01	ns	ns	p<0.01
	f	ns	ns	ns	p<0.01
HYPT	m	p<0.01	ns	ns	p<0.01
	f	ns	ns	ns	p<0.01
MI	m	p<0.01	ns	ns	p<0.01
	f	ns	ns	ns	p<0.01
ARRH	m	p<0.01	ns	ns	p<0.01
	f	ns	ns	p<0.01	p<0.01
CHF	m	p<0.01	ns	ns	p<0.01
	f	ns	ns	p<0.01	p<0.01

Table 7. Comparison of Healty group vs DM, AP, HYPT, MI, ARRH, CHF considering 4 ECG parameters related to T wave.

		T ratio	T PCA	T round	TWAD
DM	m	p<0.01	p<0.01	p<0.01	p<0.01
	f	p<0.01	p<0.01	p<0.01	p<0.01
AP	m	p<0.01	p<0.01	p<0.01	p<0.01
	f	p=0.012	p<0.01	p<0.01	p<0.01
HYPT	m	p<0.01	p<0.01	p<0.01	p<0.01
	f	p<0.01	p<0.01	p<0.01	p<0.01
MI	m	p<0.01	p<0.01	p<0.01	p<0.01
	f	p<0.01	p<0.01	p<0.01	p<0.01
ARRH	m	p<0.01	p<0.01	p<0.01	p<0.01
	f	p<0.01	p<0.01	p<0.01	p<0.01
CHF	m	p<0.01	p<0.01	p<0.01	p<0.01
	f	p<0.01	p<0.01	p<0.01	p<0.01

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