Cardiac Syndrome X Electrocardiographic Profile Using High-Resolution Signal-Averaged VCG

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Abstract

Cardiac syndrome X (CSX) is a clinical condition characterized by angina, positive stress test and negative coronary angiography. Myocardial ischemia is suggested to influence the typical ischemic changes in the electrocardiogram (ECG) observed during stress test. The aim of this study is to obtain CSX patterns of the vectorcardiographic (VCG) loops in the horizontal (H), frontal (F) and right sagittal (RS) planes of the Frank corrected orthogonal leads (X,Y,Z) and to assess their similarity with the reference VCG loops of normal subjects.

The results after synthesis of the VCG patterns in H, F, RS planes and identification of the magnitudes, angles and rotation of the maximal QRS and T vectors, as well as the angles of instant vectors at 0.01-0.04s suggest that CSX electrocardiographic profile could be considered as a variant of the normal profile, however, it contains some VCG changes seen in the ischemic heart disease.

1. Introduction

The concept of cardiac syndrome X (CSX) includes patients, mainly women before or in the period of menopause fulfilling the following three major criteria: chest pain, positive exercise-strain test, normal coronary angiogram [1-3]. The chest pain is a leading symptom of these patients, usually stronger and more prolonged than the typical angina pectoris which is also more difficult to control by the standard antiischemic therapy [4,5]. Impaired functional cardio-vascular capacity is usual for these patients. As a result, they are often re-hospitalised, new unnecessary angiograms are done and quality of life of these patients worsens [6].

Investigations on the prognosis of these patients show that their life-expectancy does not differ considerably from the rest of the population, excluding those with rhythm and conductance disorders like left-bundle branch blocks, as such patients is likely to develop dilated cardiomyopathy (NLHBI WISE study with mean duration of follow-up for 5.2 years) [7].

Analysis of the high-resolution vectorcardiogram (VCG) enables detection of electrical activity of individual and/or typical for patient group fragments of the cardiac muscle that opens up a possibility of developing a qualitatively new diagnostic method. Comparing VCG to the standard electrocardiogram (ECG), the former shows the advantage of having better sensitivity for analysis of the repolarization process and myocardial ischemia [8-10].

The signal-averaged VCG is an informative electrophysiologic method for assessment of the myocardial condition and for classification of an individual VCG patient profile either to a population of normal subjects or to a particular cardiac pathology. The aim of this study is to obtain CSX patterns of the VCG loops in the horizontal, frontal and right sagittal planes of the Frank corrected orthogonal leads (X,Y,Z) and to assess their similarity with the reference VCG loops of normal subjects.

2. Materials and methods

The study involved 56 high-resolution ECG recordings (1kHz) at rest collected from 28 women (mean age 55.3±9.5 years) using 12-channel ECG data acquisition system [11] in the Clinic of Cardiology, Medical University – Sofia, and in the Clinic of Cardiology, University Hospital of Emergency Medicine "Pirogov", Sofia, Bulgaria. All patients were with fulfilled criteria for CSX at the period of pre- or postmenopause and with "clear" coronary arteries verified from angiography or multi-slice computed tomography. Stratification by risk factors, comorbidity and pharmacological management have been done using a standardized protocol.

The study was based on assessment of the high-resolution Frank corrected orthogonal leads (X,Y,Z), synthesized from the 12-standard ECG leads by applying the transformations (1) [12]:

$$\begin{aligned} X &= 0.4*II\text{-}0.8*(II+III)/3+0.2*V5+0.5*V6+0.1*V4 \\ Y &= 0.3*III+0.8*II+0.5*(II+III)/3\text{-}0.2*V5\text{-}0.3*V6 \\ Z &= \text{-}0.1*III\text{-}0.2*II+0.4*(II+III)/3\text{-}0.3*V1\text{-}0.1*V2 \\ &\quad \text{-}0.1*V3\text{-}0.2*V4\text{-}0.1*V5+0.4*V6 \end{aligned} \quad (1)$$

The mean duration of all CSX recordings was 11.8±4.8 minutes. Synchronous averaging of the normal atrio-ventricular complexes in each record was applied for calculation of the averaged P-QRS-T waveforms for each orthogonal lead X, Y, Z, and construction of the averaged spatial VCG loops in the horizontal (H), frontal (F) and right sagittal (RS) planes. The VCG loops of all CSX recordings were then synchronously superimposed to obtain a pattern of the spatial VCG loop, typical for CSX. The patterns of its three projections in H, F, RS planes were used for calculation of the maximal QRS and T vectors (magnitudes and angles) and the instant vectors (angles) of ventricular depolarization at 0.01s, 0.02s, 0.03s, 0.04s.

The reference VCG data were adopted from Frank's study of 100 normal subjects [13].

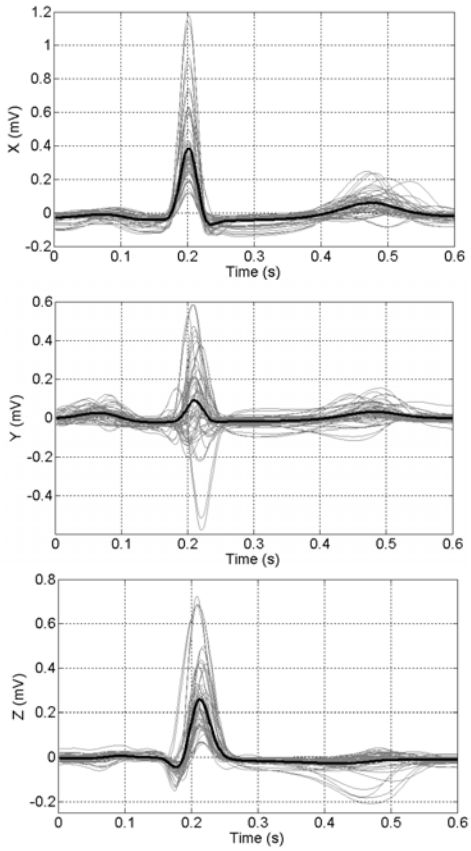

Figure 1. Profiles of the orthogonal X, Y and Z leads in women with CSX. The averaged P-QRS-T pattern (black curve) is obtained from all 56 individual recordings (grey curves).

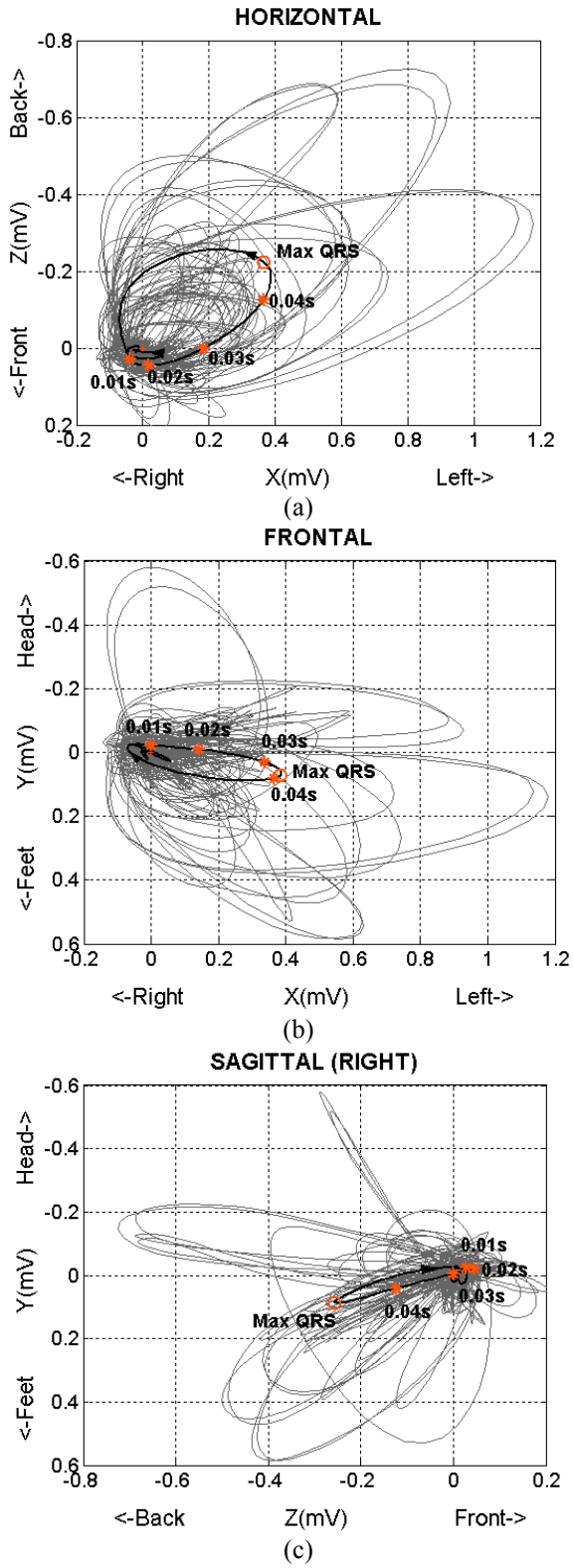

Figure 2. Spatial VCG loop projections in H, F, RS planes of women with CSX. The averaged loop (black curve) is obtained from all 56 individual recordings (grey curves). The instant vectors ('*' marks) and max QRS vectors ('o' marks) are depicted above the mean loops.

Table 1. Basic results found for the VCG profile in women with CSX after synthesis of the VCG patterns in H, F and RS planes and identification of the magnitudes, angles and rotation (clockwise or counter-clockwise) of the maximal QRS and T vectors, as well as the angles of the instant vectors. Reference VCG profile in normal subjects is presented.

VCG indices	Horizontal H-plane		Frontal F-plane		Right Sagittal RS-plane	
	Normal	CSX	Normal	CSX	Normal	CSX
Magnitude max QRS (mV)	1.12±0.21	0.45±0.26	1.18±0.15	0.43±0.24	1.16±0.12	0.34±0.19
Angle max QRS (°)	335±30	329±16	42.3±7.2	11±39	174.3±22.3	161±38
Rotation of QRS vectors		100% Counter-clockwise		75% Clockwise		48% Clockwise
Magnitude max T (mV)	0.58±0.18	0.09±0.07	0.46±0.11	0.09±0.06	0.52±0.12	0.07±0.05
Angle max T (°)	52±12.5	19±57	36.2±10.1	25±48	33.7±30.2	51±70
Rotation of T vectors		21% Clockwise		64% Clockwise		71% Clockwise
Angle instant vectors (°):						
0.01s	120±41	143±41	152±72	268±85	348±50	318±92
0.02s	54±25	69±50	40±53	356±54	30±38	335±120
0.03s	12±12	0.3±24	36±12	5±31	34±22	281±110
0.04s	355±20	341±17	46±18	12±29	88±16	162±49

3. Results

The data from all 56 recordings of women in CSX are summarized above, including the P-QRS-T patterns in the orthogonal leads (Figure 1), the spatial VCG loops (Figure 2) and the basic measurements from the VCG profile compared to the reference norm (Table 1).

4. Discussion and conclusions

In CSX, we observe that the horizontal projection of the averaged QRS-loop (Figure 2a) conforms to the common characteristics of the normal VCG:

- counter-clockwise rotation, which is observed in all individual loops participating in the averaging (100%);
- the length of the loop exceeds its width with about 1.5 to 3 times;
- the maximal vector is directed toward the left posterior quadrant (329±16°);
- the apical (0.02s) vector, which has an important diagnostic significance, is directed toward the left anterior quadrant (69±50°);
- the maximal magnitude of the QRS vector is observed at about 0.03-0.04s.

However, the mean magnitude of the maximal QRS-vector in CSX (0.45mV) appears to be below the mean value of the normal subjects, and even below the low limit of the norms in women (0.8mV).

Besides, the horizontal projection of the averaged T-loop in CSX appears with highly extended elliptical form and maximal vector directed anteriorly to the left (19±57°) – characteristics, which are in concord to the norm. The mean magnitude of the maximal T-vectror (0.09mV) is however below the mean value in normal subjects and even below the low limit of the norms in women (about 0.1mV).

In the frontal F-plane, the projection of the averaged QRS-loop in CSX (Figure 2b) appears with the following characteristics:

- the contour is extended, relatively narrow, with initial part directed superiorly to the right, and the main parts of both afferent and efferent limbs directed toward the left inferior quadrant;
- the rotation of the individual QRS vectors is mainly clockwise (75%), although most of the observed QRS-loops are shifted horizontally compared to the normal position;
- the instant 0.02s vector is directed toward superior left quadrant (356°), which is observed in about 30% of the normal subjects, however, the instant 0.03s and 0.04s vectors are directed toward the left inferior quadrant (5° and 12°, respectively), which is also typical for the norm.

In CSX, the averaged T-loop in the frontal F-plane appears mainly in the inferior left quadrant, being more extended and narrower than the T-loops in the other projections. The rotation of the individual T-loops is more often (64%) in clockwise direction, typical for the norm, and it follows the rotation of the QRS-loop. The mean magnitude of the averaged maximal T-vector is below the mean amplitude of the norm, such as the measurements in

the horizontal plane.

In the right sagittal RS-plane (Figure 2c), we observe specific characteristics of the averaged QRS-loop in CSX:

- the contour is smoothed, with elliptical form and slight curvature;
- the rotation of the averaged QRS-loop is clockwise, although the rotations of the individual QRS-loops are almost equally likely to appear in clockwise (48%) or counter-clockwise (52%) direction. This specific feature observed for CSX (the QRS-loops in normal subjects typically follow clockwise direction) is reflected in the values of some instant vectors;
- the maximal QRS vector is directed toward the posterior-inferior quadrant (161°), however, the apical (0.02s) vector has anterior-superior direction (335°), the 0.03s vector has superior direction (281°), and just 0.04s vector is slightly shifted toward inferior direction (162°).

Specific features are found also in the RS-plane projection of the averaged T-loop in CSX. The position of the T-loop is in the anterior-inferior quadrant with rotation of the maximal T-vector (51±70°) closely distributed to the typical orientation in normal subjects. In contrast to the specific normal form of the T-loop, which is typically more extended and narrower than the one in the horizontal plane, the averaged T-loop in CSX appears with rounded form and suppressed magnitude of the maximal T-vector (0.07mV).

In conclusion, the performed analysis indicates that the vectorcardiographic profile at rest of CSX has characteristics, which in their predominant part could be interpreted as variant of the normal vectorcardiographic profile. However, some features, mainly related to the T-loops refer to some details in the VCG profile which are specific for the ventricular repolarization in myocardial ischemia. These deviations from the norm are seen in different combinations – shifting of the direction, rotation and form, or normal direction with pathological rotation and form of the vectorcardiographic images.

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