TIME-FREQUENCY ANALYSIS OF THE HEART-RATE VARIABILITY DURING PHYSICAL TEST FOR EARLY ISCHEMIA DETECTION

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ABSTRACT

This paper presents the time-frequency analysis of the heart rate variability (HRV) during four physical states in order to distinguish between two groups of ischemic and healthy subjects. The aforementioned physical states comprise resting, breath control, deep breathing and standing. The time-frequency results are divided into the VLF, LF an HF bands. Our results show greater variance in VLF and LF powers of healthy subjects during the resting state. During breath control the increase in HF power and during deep breath increases in HF and LF band powers are noted for healthy subjects when compared to the ischemic group. During periods of standing, higher power increases in the LF band and longer dampening times were observed among healthy subjects when compared with ischemic subjects. These results have been analyzed and evaluated for use in early detection and verification of the symptoms of the disease.

1. INTRODUCTION

TSCHEMIC heart disease constitutes one of the most common fatal diseases in the western hemisphere. Myocardial ischemia is caused by a lack of sufficient blood flow to the contractile cells and may lead to myocardial infarction and may cause heart failure, arrhythmias, and death [1]. During past decade analyzing cardiac signal such as ECG an HRV signal has become the noninvasive test most widely used for detecting cardiovascular diseases. Time-frequency analysis of the heart-rate variability provides insight into the underlying physiological processes of the autonomic nervous system (ANS) .

In our previous study ANS process was analyzed during physical test using HRV time-frequency representation [2]. Vila et al analyzed HRV time frequency distribution and shows it's advantage to classic spectrogram, and as an application the use their results for detecting ischemic episode. Mainnardi et al show the effects of Dipyridamole and Dipyridamole induced ischemia on the traditional spectral parameters of HRV in normal and coronary artery disease (CAD) patients, who underwent Dipyridamole Echocardiography Test (DET). Tan et al used Wavelet transform (WT) to investigate whether variation in autonomic tone was associated with spontaneous coronary spasm in patients with variant angina by analysis of heart rate variability (HRV). HRV indices were calculated at 10 second intervals with the continuous WT, and analyzed within 30 minutes preceding ST-segment elevation. Result shows that High frequency (HF; 0.15_2.00 Hz) increased significantly during the 4 minutes prior to ST-segment elevation, low frequency (LF; 0.04_0.15 Hz) decreased significantly during the period from 10 to 5 minutes and increased significantly during the 2 minutes prior to ST-segment elevation, theLF/HF ratio decreased significantly during the period from 10 to 3 minutes and increased significantly during the 2 minutes prior to ST-segment elevation [3].

2. MATERIAL & METHOD

2.1- Recording Data

Data is recorded from patients who's suffering from chest pain and has been sent to Tehran Cardiology Center for exercise test. Our selected group contains 10 normal subjects (those who have no change in ST segment during exercise test) and 10 patients with Coronary Artery disease (those who have ST elevation in exercise test). All subjects have no history of heart disease, no history of diabetes and they don't take any drug for more than 48 hours before the test. All subjects have normal resting Electrocardiogram (ECG). Before the subjects taking exercise test, their ECG recorded during four physical situations that will discuss later. ECG was recorded from lead II by Power Lab ML865 recording. Data was sampled at the rate of 1 KHz and filtered with 200Hz low pass filter and 50 Hz notch filter. R peak detected using subject dependent threshold, and HRV constructed from R-R time series using Spline interpolation with sampling rate on 10 Hz. Each subject should pass following physical test to accomplish our test.

- **Resting:** During this test subjects lay down on bed in a quiet room for and their ECG recorded for about 5 minute.

- **Breath control:** This test consist of three phase. During the first phase that last about two minute subjects rest on the bed the same as the resting test. During second phase, that last about two and a half minute subjects control their breathing and keep it at the rate of 12 breathing per minute by using watch. During the third phase subjects rest like the first phase.

- **Deep breath:** This test consist of three phase. During the first phase that last about two minute subjects rest on the bed the same as the resting test. During second phase, that last about one minute subjects control their breathing and keep it at the rate of 6 breathing per minute by using watch. They should have deep breath. During the third phase subjects rest like the first phase.

- **Standing:** During this test after 2 minute of resting subjects stand up from bed and stand on the floor for about 5 minute.

2.2.- Signal Processing

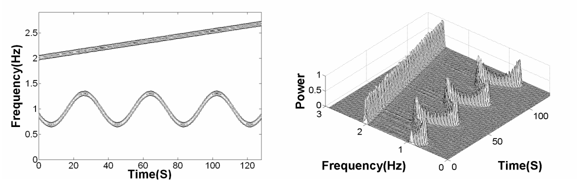
Time-Frequency distributions used in this paper can be divided in to two major group of parametric and nonparametric time-frequency distribution. As a parametric distribution we used Auto regressive (AR) model for estimation of power spectrum. For parameter estimation of the AR model we used Forward Backward method.

For nonparametric method we choose some members of Cohen class. In general Cohen class time-frequency distribution can be defined by equation (1) [4].

$$C_x(t,\omega,\phi) = \iint \phi(\theta,\tau) A_x(\theta,\tau) e^{-j(\omega\tau - t\theta)} d\theta d\tau \quad (1)$$

Above equation is the square integral of time-frequency distribution kernel (ϕ) multiply in Ambiguity function of desired signal (A). For deriving ambiguity function of a signal we need to estimate Fourier transform of correlation function of that signal (equation 2).

$$A_x(\theta,\tau) = F_t\ [x(t+\tau/2)x^*(t-\tau/2)] = F_t\ [R_x(t,\tau)] \quad (2)$$



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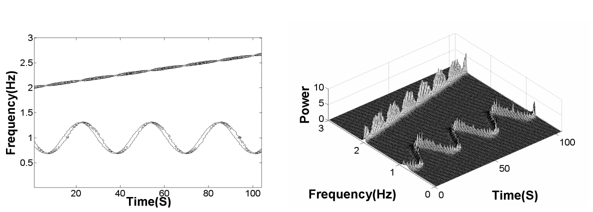

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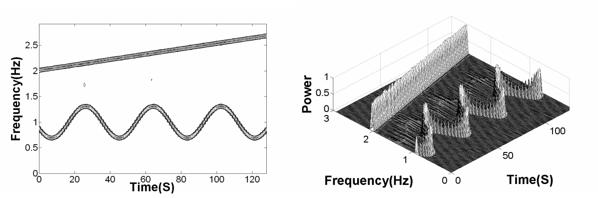

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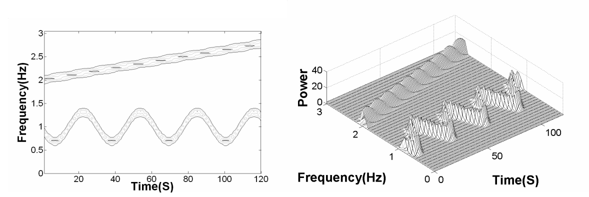


(d)

Figure 1. *Simulated signal time-frequency distributions using Bessel (a), AR (b), Choi-Williams (c), and STFT (d) distributions.*

Cohen class time-frequency distributions used in this paper are STFT, Bessel and Choi-Williams distribution. After implementing these distributions using Matlab, they have all tested on simulated data consist of a linear chirp plus Cosines frequency modulated signal (equation 3 and figure. 1).

$$x(t) = \cos\left(2\pi t + 10\pi\cos(0.02\pi t)\right) + \cos\left(2\pi(2+0.001t)t\right) \quad (3)$$

3. ANALYSIS & RESULT

After extracting HRV signal from ECG and removing HRV DC component, time frequency distribution applied to the signals. For comparing time-frequency distributions in the same condition, we use them with 128 dot windows and 50% overlap. AR model with degree of 69 chose for AR time-frequency representation. Hanning window was chosen for STFT. In Bessel time frequency distribution $\alpha = 1.49$ and in Choi-Williams distribution $\sigma = 10$ was chosen for HRV time-frequency representation.

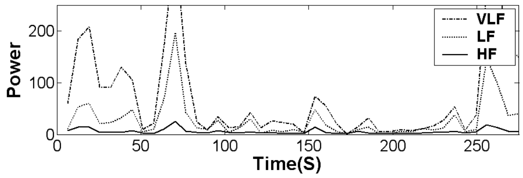
The HRV time-frequency distribution results was divided into three frequency band: Very low frequency (VLF) (0.003-0.04Hz), low frequency (LF) (0.04-0.15Hz) and high frequency (HF) (0.15-0.4Hz). Where increase in LF energy contribute to increase in sympathetic activity, and increase in HF energy contribute to increase in parasympathetic activity. Result of HRV signals time-frequency distribution in different physical states was mentioned below (fig2).

- **Resting:** During resting test most signal power concentrate in LF and VLF bands. In both normal and ischemic subjects we have change in power at these two bands, but variance of power in normal subject was greater than ischemic ones.

- **Breath control:** During breath control the HF power increase in both group. Increase in HF power in normal subject was reported before [2], but this increase of power in normal subjects HF band was more than ischemic ones.

- **Deep breath:** During deep breath the HF, LF power increase in both group. Increase in HF power is more than LF power due to more activation of parasympathetic system. Increase in HF and LF power in normal subject was reported before [2], but this increase of power in normal subjects HF and LF bands was more than ischemic ones.

- **Standing:** In standing due to sudden decrease of blood pressure HRV changes is obvious. In standing first we have decrease in HF energy with increase in LF energy. After a while because of increase in parasympathetic activity and decrease of sympathetic activity, HRV become normal [5]. In normal subject these changes are greater than in ischemic ones, and take more time to damp.



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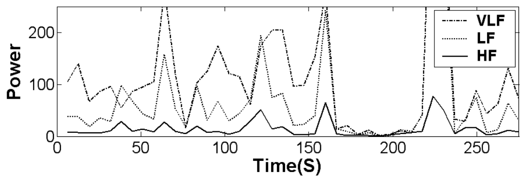

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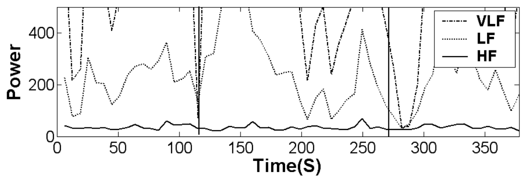
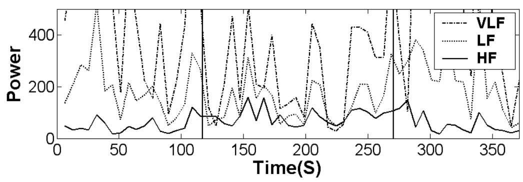


(a-2)



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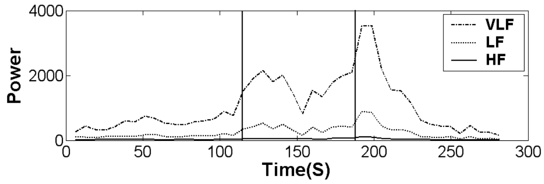

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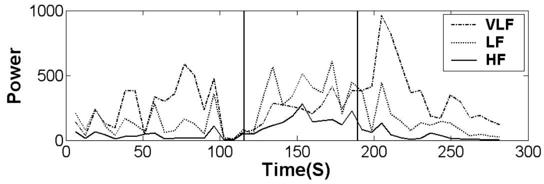

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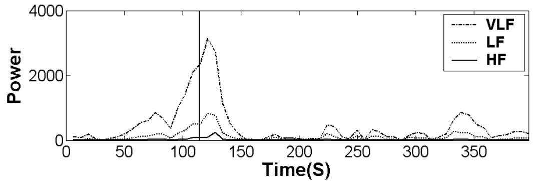

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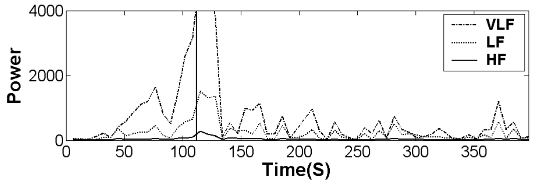


(b-4)

Figure 2. *Time-frequency analysis using Bessel distribution in one ischemic (a) and normal subject (b), during resting(1), breath control(2), deep breath(3) and standing (4) test.*

4. DISCUSSION

In this paper HRV time-frequency representation used for distinguishing normal subject from ischemic ones. Both groups have chest pain and attend to hospital for exercise test. HRV time-frequency representation calculated during four physical states and difference between groups was discussed. Among different time frequency distributions Bessel kernel shows better resolution and help to clear difference between two groups. For having quantified parameter to compare members of both groups during different physical states, we used power mean and variance. Parameters used in this comparision are as follow:

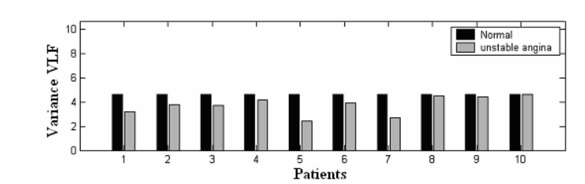
- rest: power variance in VLF and LF bands.

- breath control: difference between power mean during breath control and resting period before control in HF band.

- Deep breath: difference between power mean during deep breath and resting period before deep breathing in LF and HF bands.

- Standing: power mean in a period starting 30 seconds before standing till 20 seconds after standing in all three bands.

After extracting these parameters, the average of each parameter was calculated in normal group and the calculated average compare against the same parameter of each member of ischemic group (fig 3). Parameters show that the best difference between two groups is in standing state.



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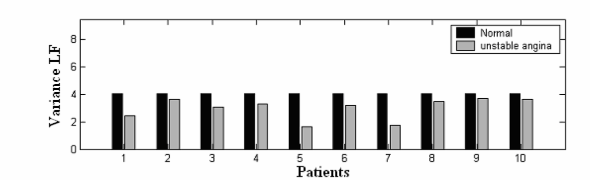

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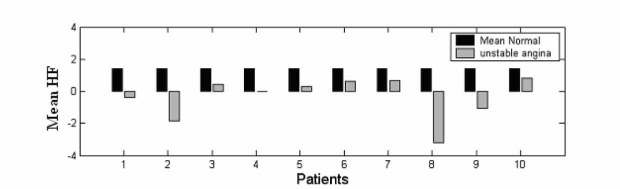

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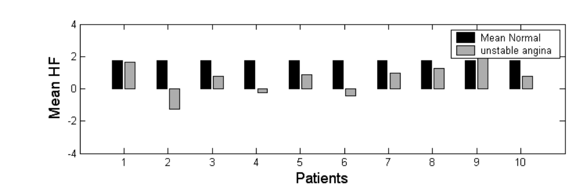
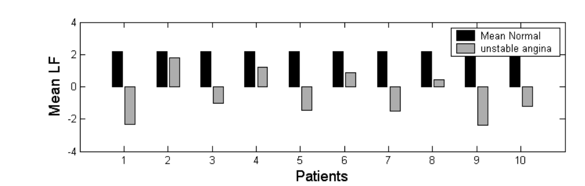


(c-1)



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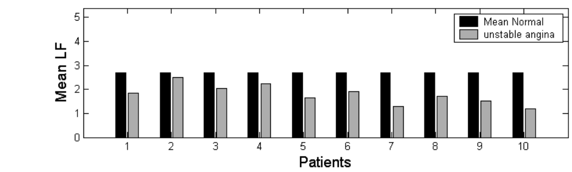

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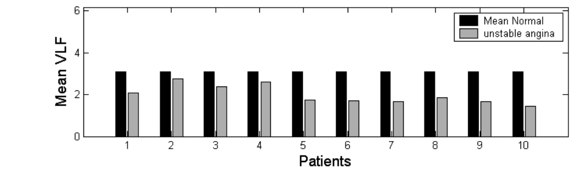

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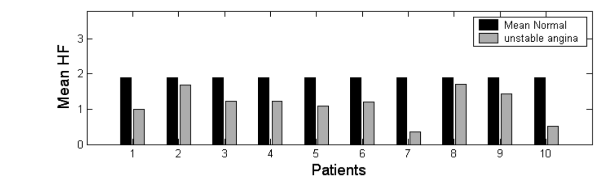

(d-3)

Figure 3. *Comparing each member of both groups using Bessel distribution during resting(a) in VLF(1) and LF (2) bands, during breath control in HF band (b), during deep breath (c) in HF (1) and LF (2) bands and at the time of standing (d) in LF(1), VLF(2) and HF(3) bands.*

5. REFERENCES

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