Primary Study on Correlation Dimension of 24h HRV in Different Frequency Domains

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***Abstract*—Heart Rate Variability (HRV) contains abundant information of cardiovascular regulation, which has been used as a non-invasive method to evaluate the function status of cardiovascular system. In this work, we mainly analyzed a non-linear parameter—correlation dimension (CD) extracted from different frequency domains of 24h HRV. Coronary heart disease (CHD) patient and healthy control were studied as contrast, and 24h HRV data recorded by Holter in clinic and from MIT-BIH Database was analyzed. The whole 24h data was respectively divided to four sections in time scale. CD was extracted from HRV before and after wavelet decomposition in four time sections. Results indicated the curve of CD from HRV in VLF is similar to that from HRV before wavelet decomposition. This verified most non-linear information was contained in VLF of HRV reported by other researchers. HRV signals in VLF from CHD patient group and control group were primarily studied. Average CD value in the third time section from healthy control was a little larger, which probably indicated in the afternoon the complexity was a bit higher in cardiovascular system of healthy control. The conclusion needs further study and statistic analysis to support.**

***Index Terms*—Heart rate variability, Wavelet transform, Very low frequency, Correlation dimension.**

I. Introduction

During the past three decades, heart rate variability (HRV) was verified to contain abundant information of cardiovascular system. In 1970s, Wolf firstly discovered HRV was correlated to death risk evoked by myocardial infarction [1]. In 1980s, Ewing studied R-R interval of diabetic to detect injured status of autonomic system [2]. Akselrod combined spectrum analysis with pharmacology and physiology, and primarily explained physiological significance covered in peak of short HRV [3]. Afterwards he discovered that long HRV contains characteristics of chaos and fractal. Since 1990s [4], HRV has been used as an important index in clinic and there were many studies on assessment of cardiovascular autonomic nervous system [5].

In studies on cardiovascular diseases, HRV data has been analyzed both in time domain and frequency domain. Wavelet theory provides a new tool for HRV analysis in time-frequency domain, which could give more detail information in multi-frequency bands. With development of chaos and fractal theorem, non-linear parameters were more and more extracted from HRV to obtain non-linear features which were unavailable by time-frequency methods of analysis. These parameters include Lorenz plot, Correlation dimension, approximate entropy and complexity, etc.

This paper mainly studied 24h HRV recordings from CHD and healthy controls in different frequency domains. One non-linear parameter—correlation dimension was extracted from 24h HRV which was divided to four time sections. Primary results indicated that non-linear information mainly contained in very low frequency domain, and there was some difference in correlation dimension curve between CHD and controls.

II. Methodology and Data Analysis

A. Methodology of 24h HRV processing

Spectrum of HRV mainly was usually divided into four frequency domains, including Ultra low frequency (ULF: 0-0.0033Hz), very low frequency (VLF: 0.0033-0.04Hz), Low frequency (LF: 0.04-0.15Hz) and High frequency (HF: 0.15-0.4Hz). Different frequency domain contains different physiological information. HRV in LF and HF were widely studied to evaluate the regulation function of autonomic nervous system.

After getting rid of the noise above 0.4Hz in frequency domain by filtering, wavelet transform was used to decompose HRV to four different frequency domains including ULF, VLF, LF and HF. Here Daubechies 5 wavelet was adopted. HRV was decomposed to 5 levels and then reconstructed in four different frequency domains.

24h HRV was divided into four sections in time scale, that is: 00:00-06:00; 06:00-12:00; 12:00-18:00; 18:00-24:00. CD was respectively extracted from these sections in three domains named VLF, LF and HF.

Here CD was calculated from power spectrum analysis. The algorithm was based on the view that the power spectrum of HRV satisfied power-law relation as $S_x(\omega)=\sigma_x^2/|\omega|^\gamma$, so the correlation dimension could be calculated by the following formula [6]:

$$Dr = \frac{5-a}{2} \tag{1}$$

Where a can be obtained by least square fitting of the spectrum curve by an approximate linear line.

B. Data analysis

We analyzed 24h HRV recordings from 30 CHD patients

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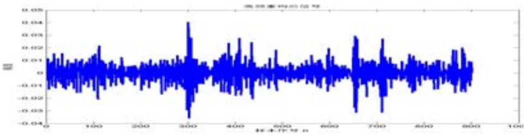
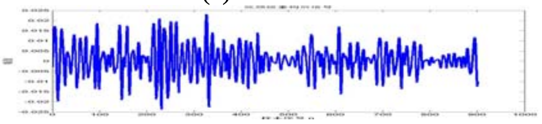
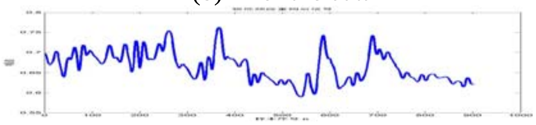
and 30 controls in all. As an example, here was one segment of 24h HRV recordings from a CHD patient. The VLF, LF and HF of the data were respectively shown in Figure 1.



(a)HF of the data



(b)LF of the data



(c)VLF of the data

Fig.1 One segment of 24h HRV From a CHD patient

24h HRV recordings from the CHD patient and one healthy person were analyzed. CD in four time sections was calculated respectively. Figure 2 showed the results from the filtered recordings before wavelet decomposition (Dashed line: healthy, real line: CHD. Same in the following figures).

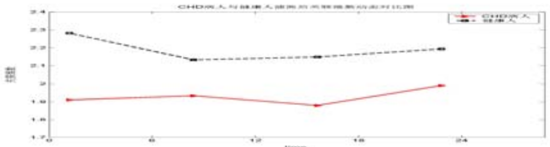
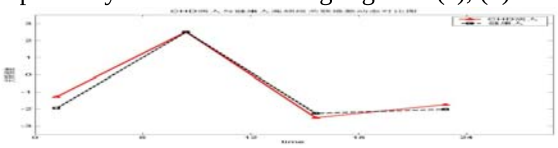


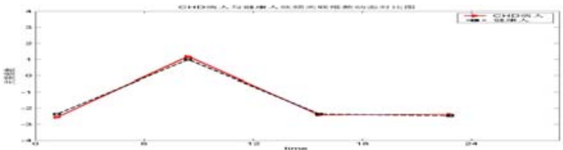
Fig 2 correlation dimension of the 24h HRV

From the results in Figure 2, the curve of CD from the healthy control was above that from the CHD patient.

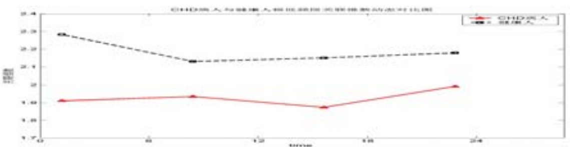
The CD curves in HF, LF and VLF domains were respectively shown in following Figure 3 (a), (b) and (c).



(a)Result in HF



(b) Result in LF



(c) Result in VLF

Fig.3 Correlation dimension from recordings in different frequency domain

From the results in Figure 3, it could be seen that in HF and VF, there was no much difference between CD curves of the healthy control and the CHD patient. While in VLF, the curve of CD from the healthy control was above that from the CHD patient, which is similar to the result from the 24h HRV data without wavelet decomposition in frequency domain.

The average CD of HRV in VLF from 30 CHD patients and 30 controls was respectively given in Figure 4 as follows.

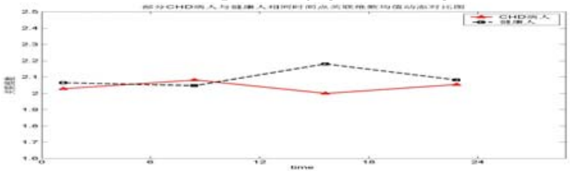


Fig.4 Correlation dimension from two groups.

We could see for these two groups, CD value in 12:00-18:00 is different, and the value from healthy controls is larger than that from CHD patients. Statistics results also showed only the CD in 12:00-18:00 was significantly different between two groups.

III. Conclusion

From the results we obtained, the CD of 24h HRV data without decomposition in frequency domain was similar to the result of data in VLF domain, which means most non-linear information of 24h HRV contained in VLF domain. This result was accordant to some studies from other researchers. Compared the CD curves of 24h HRV in VLF between CHD patient group and healthy control group, there was some difference in the third time section. The value from controls was obviously larger than the result from CHD patients, which probably means in the afternoon the activities of cardiovascular system of healthy people were more complicated, and the corresponding HRV contained more non-linear information than CHD patient. This study was primary and the results needed further study to support.

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References

[1] Wolf M, M Varigos G, et al. Sinus arrhythmia in acute myocardial infarction. Med J Aust, 1978, 2: 52-53 DOI 10.10007/s002149800025
[2] Ewing DJ, Martin CN, Young RJ, et al. The value of cardiovascular autonomic function tests: 10 years' experience in diabetes. Diabetes Care, 1985, 8: 491-498
[3] Akselord S, Gordon D, et al. Power spectrum analysis of heart rate fluctuation: a quantitative probe of beat to beat cardiovascular control. Science,1981, 213: 220-222
[4] Babloyantz A, Destexhe A, Is the normal heart a periodic oscillator? Biol. Bybern, 1988, 58: 203
[5] Chen yunzhen, Lei han, Xie yang, et al., Quantitative method to detect activity of cardiac vegetative nerve—spectrum analysis of heart rate. Chinese Journal of Cardiology，1992，20(2) : 101-104
[6] Wang yongchen,Wu xiaofei, Application of Fractal Dimension Estimation for Sea Clutter in the Detection of Sea-Surface Targets, Modern radar [in Chinese],2000,22(5):28-31,36