A Chaotic Dynamic Study of Autonomic Nervous System Activities on Heart Rate Variability and Peripheral Blood Pressure.

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ABSTRACT

This paper describes the effect of autonomic nervous activity on Heart rate variability and peripheral blood pressure with power spectral analysis and its characteristics of chaotic attractors.

The aim of this paper is to access the applicability of spectral and dimension analysis of heart rate variability and peripheral blood pressure, attributed to changes in autonomic nervous system activity.

About 60 mininutes of Heart rates and synchronized peripheral blood pressure were recorded on 10 healthy man while various mental and physical conditions.

The results shows the availability to evaluate the autonomic nervous activities.

1. INTRODUCTION

The most of observed biological signals are seemingly random dynamics. So far, the common methods to analysis the biological signals are based on stochastic process.

Chaos theory suggests the other view points to analysis of these signals[1].

It is well known that the beat to beat variations on heart rate variability are shown chaotic dynamics and also, the pulsation in human capillary vessels, peripheral blood pressure[2,3].

In this study, we will show characteristics of chaotic attractor of heart rate variability and peripheral blood pressure change while mental and physical conditions with dimensional analysis, attributed to autonomic nervous system partially based on Tsuda's hypothesis.

Recently, power spectral analysis of heart rate variability has been used as a noninvasive parameter of autonomic nervous activity[4,5]. The power spectrum of the heart has two major components. Low frequency component appears to be an index of sympathetic activity. High frequency component represents parasympathetic activity. We also show power spectrum of peripheral blood pressure and its chaotic dimensions to investigates the effect of autonomic nervous activities.

2. EXPERIMENTAL SYSTEM

We design a experimental system which is consists of ECG, PBP acquisition boards, A/D converter (DT2801, 12 bit), peripheral storage device, printer , PC486 and SUN sparc station. PC and workstation are combined with PC-network file system using Ethernet cable. PC is data acquisition and preprocessing system while nonlinear time series analysis and power spectral analysis are conducted based on SUN workstation.

The figure 1 shows the experimental setup.

About 60 minutes of heart rate which are induced one channel recorder from lead II, and peripheral blood pressure which are using photo diode and photo transistor were directly recorded on 10 healthy man while various mental and physical condition.

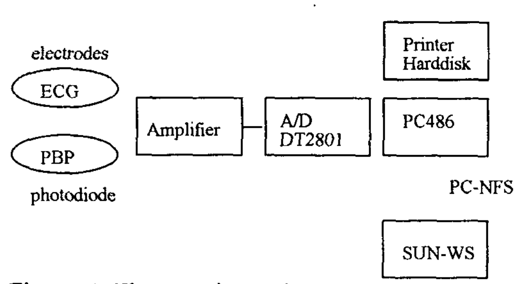


Figure 1. The experimental setup.

We detect QRS complex of recorded 60 minutes, 250 Hz, electrocardiogram using modified Tompkin's algorithm [6] and convert into time series of heart rate variability.

3. POWER SPECTRUM ANALYSIS

The time series of pulsation of in human capillary vessels, peripheral blood pressure and HRV were first applied to the spectral analysis to evaluate sympathetic and parasympathetic nervous system activity. We use several existing method to transform RR interval into the heart rate variability to find out optimal algorithm for our experimental time series data. We use Welch periodogram, count method and integral pulse frequency modulation method[7]. It is very important to derive a heart rate signal from

electrocardiogram. If derived heart rate signal do not close match its input ECG signal, spectral analysis often fails to represents autonomic activities.
The formula (1) represents one of the heart rate variability algorithm, interval spectrum.

$$hj = (Tj+1-Tj)(j-1)\Delta T - \sum_{k=1}^{j-1} Tk)/Tj+Tj \quad (1)$$

where
Tj ; R time interval between j+1 th and jth Rpoint.
T ; Time sum of overall RR interval
N ; Number of R peaks
$\Delta T = (T/N)$; mean time interval
h_j ; j th transformed impulse

The figure 2 shows transformed heart rate variability of obtained electrocardiogram and figure 3 represent pulsation of peripheral blood pressure .

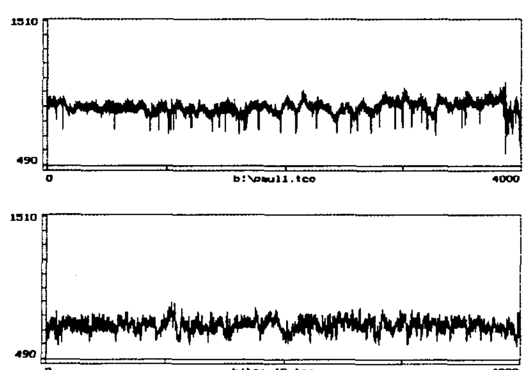


Figure 2. Heart rate variability

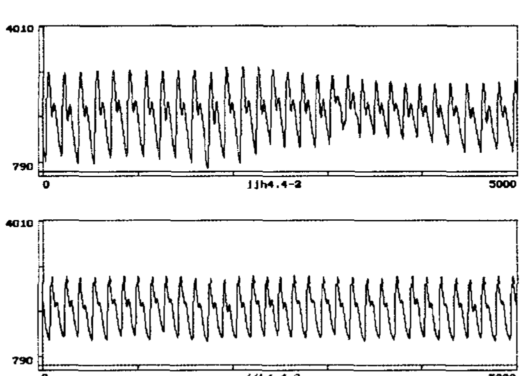
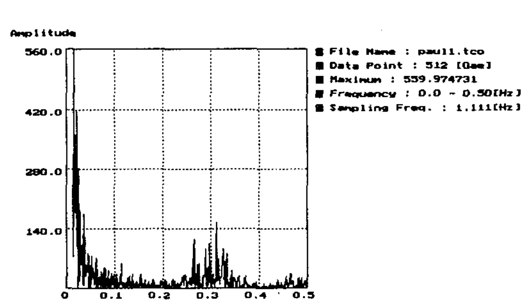


Figure 3. Pulsation of PBP



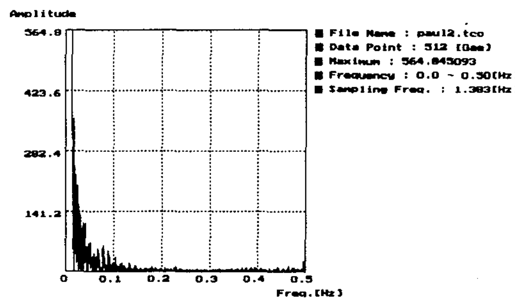


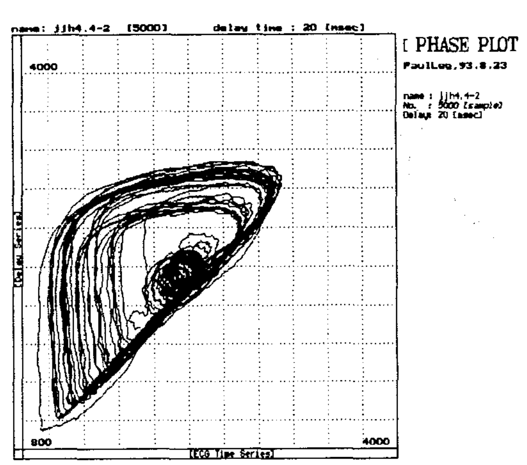
Figure 4. The power Spectrum

The figure 4. shows the power spectrum of experimental time series data.

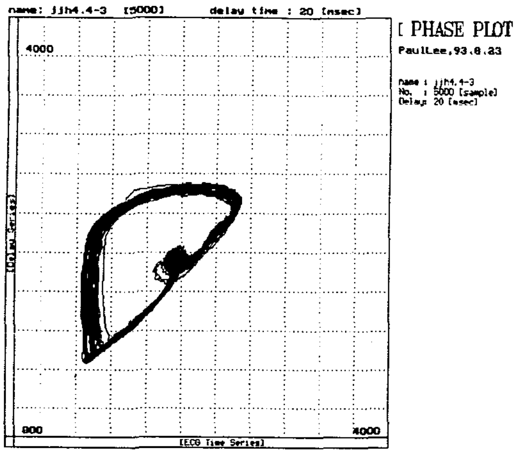
4. ANALYSIS OF CHAOTIC ATTRACTOR

It is well known fact that the HRV and PBPV are chaos signal. In order to compare the relationship between autonomic nervous activity and its chaotic dynamic changes, Quantitative and qualitative characteristics of chaotic attractors are investigated using nonlinear time series analysis tool which were organized by us[8,9]. We construct a vector in an M dimensional space

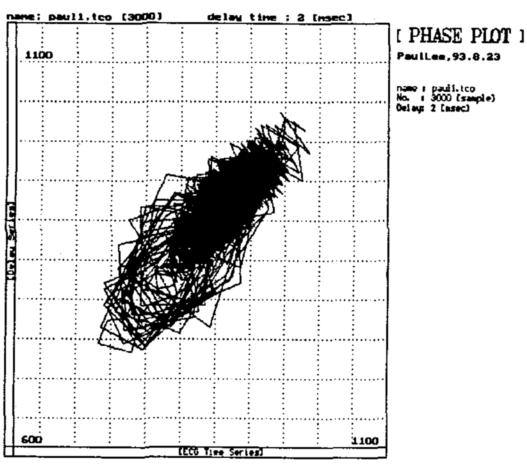
X(t) = { x(i) , x(i+d), ... , x[i+(M-1)* d]} using Takens' embedding method. The delay time d is the first local minimum point. Phase portrait used as a quantitative analysis. 2 dimension, 3 dimension and also 4 dimension phase portrait are projected into 2 dimensional monitor screen to find out proper Because we have finite set of experimental data, if we increase embedding, there is no geometrical meaning[10]. We use minimum embedding dimension. We also calculate fractal dimension, information dimension and correlation dimension derived general dimension. But it remains some problems to be solved.
The figure 5. shows the reconstructed chaotic attractor. Various attractors show us lots of information about patient's state of health.



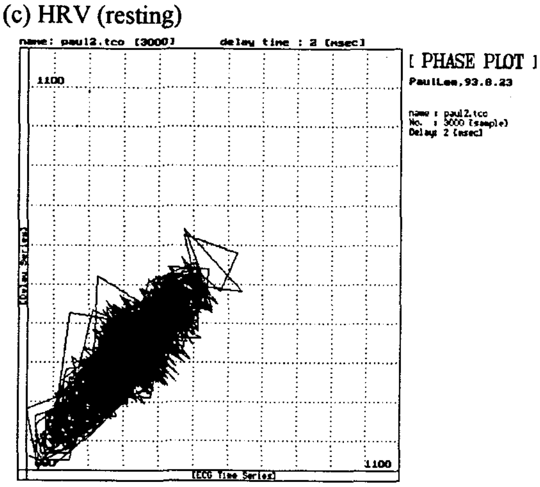
(a) PBP (resting)



(b) PBP (stressed)



(c) HRV (resting)



(d) HRV(stressed)
Figure 5. The Reconstructed Attractors

5. RESULTS AND DISCUSSION

This paper, we describes the relationship between nonlinear dynamic characteristics and its autonomic nervous activities. We carefully compare information of attractor and its power spectral density. The chaotic attractors from resting state of healthy man which means normal and harmonic dynamic activity of homeostasis, are more chaotic than those of stressed. In this study, we identify the hypothesis and extract more accurate information with PSD and dimensional analysis of HRV and PBP. The results are very perspective. If we use various kind of the number of patient data and more reliable nonlinear dynamic analysis methods, we can obtain much information which were not available conventional study.

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