Effect of Respiration in HRV Analysis using Chaos Theory

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***Abstract*—This erudite work will scrutinize and then quantify the impacts of respiration in heart-rate variability. Doing so, the critique will be on the basis of fractional mathematics along with chaos theory in two-hundred-and-fifty sick individuals who had heart-failure for the duration of twelve months. In fact, this scholarly work applied a number of non-linear methodologies, encompassing: Approximate-entropy (ApEn), FD (Fractal-dimension, and DFA (detrented fluctuation-analysis). In this scholarly work, fractal dimensions as well as the properties of fractal correlation will be employed in reflecting neuro-anatomic interaction that has been altered, which may prejudice the severe heart failure to start developing. The findings apparently portrayed that the quick-fix fractal scaling-component was appreciably lower in those individuals who had heart failure. Research has found a certain relationship between the breathing with cardiac arrhythmias signal. Moreover, those individuals with heart- failure had a lower approximate-entropy but their fractal- dimension was higher which impacted positively on the new- fangled therapy.**

***Index Terms*—heart rate variability, chaos theory, respiration**

I. Introduction

Chaos theory is established on the basis of behavioral study of dynamical systems that prove to be sensitive to initial conditions. In this theory, insignificant differences, like the ones due to rounding errors in numerical computation, lead to diverging outcomes. This leads to unpredictability of dynamical systems in the long term. Although the initial conditions of the systems determine the behavioral pattern of the systems that it is difficult to predict the deterministic nature of the systems [1].

Ideally, a number of the autonomic nervous-system manipulations on the heart rate can result to heart rate variability. It is apparently deemed that the heart rate vulnerability is greatly affected by respiration, but its manipulation level on HRV (heart-rate variability) is not well-known [2].

Also, HRV is capable of revealing the cardiac-function modulation by the respiration systems, and recording its measurements maybe deemed to be vital methodologies for purposes that are either systematic or experimental. To that effect, new methodologies have been put into practice with the aim of quantifying the heart-rate dynamics that are complicated [3].

In reality, they are likely to unearth the anomalies in time-series data, which cannot be unearthed by unadventurous static methodologies that are linear While employing the Chaos Theory to scrutinize the impacts of heart-rate in variability, this studious work will test the following hypotheses: We can alter the complicated and fractal HRV measures in those sick individuals with heart failure, and the significance of the impacts of new-fangled standard therapy [4].

Schipke, Pelzer and Arnold [5], in their study of the effect of respiration rate on short-term heart rate variability set their study in a clinical environment. In order to investigate short term reproducibility the researchers chose three respiration rates from low frequency range. In the results attained, it was noted that the heart rate was constant throughout the protocol and depending on the respiration rate; HRV recorded a difference of between 33 and 75 percent on different respiration rates. Therefore, reproducibility seems satisfactory in the short term analysis.

In another study by Hye-Sue and Lehrer [6], the researchers were interested in the impact of some respiratory rates on HRV. In this study, they relied on respiratory rates of between 3 and 12 breaths per minute. The researchers collected data 12 times at every respiration rate of 3 participants and 12 times on two participants. In line with the chaos theory, it was found out that the mean heart rate did not record a significant difference across all respiration rates.

However, the rates between 4 and 6 per minute were less than the ones at 14. The effect of the respiration rates on HRV was realized through the HR oscillation amplitudes at each respiratory rate because they were significantly different among some respiratory rates. The amplitude at rate 4 breaths per minute was significantly higher than for subsequent breaths per minute.

II. Methods

The series, which was on the basis of diagnostic-measurements that were non-invasive, engrossed two-hundred and fifty sick individuals with heart-failure. The age of these sick-individuals was over sixty five and their

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echocardiography was less than forty percent. A therapy that was standard for heart-failure was given to these sick individuals. A hundred gender-matched as well as age-matched healthy subjects that had been randomly selected were engrossed in the control group. Following the completion of their non-invasive scrutiny, the controls portrayed that the group was not using medication at the moment. This was in view of the fact that their ECG was resting normal, the echocardiography was also normal, their arterial blood-pressure was also normal, and their fasting blood-glucose was also normal. During the ECG recording, cycles of R-R hiatus were got from the high- resolution ECG, and their time-scale of recording was roughly one-hundred thousand beats. The Wave-Book 512 was employed to digitize the data from the ECG, and in order to critique that data, the data was moved to the computers.

Consequently, the R-R hiatus cycles was passed via sift that got rid of the noise, as well as eradicated those beats that were pre-mature as well as eliminated noise. Firstly, there was an automatic edition of the entire hiatus cycles and then an edition that was manual was carried out in a careful manner by use of visual inspection to each R-R hiatus [7].

Thereafter, we manually ruled out the entire portions that were questionable, and embraced those segments that had over ninety percent sinus-beats in the final critique. The ballpark figure of the fractal-dimension was from the Hurst-exponent of R-R cycles. The range re-scaled critique was employed in determining the R-R cycles Hurst-Exponent. The detrended-fluctuation analysis was employed in quantifying the fractal association HRV properties. As a matter of fact, the nonappearance or occurrence of the fractal properties of correlation will be quantified by the detrended-fluctuation analysis.

Ultimately, the approximate-entropy was employed in quantifying the inescapability or promptness of time, as well as generating information in time-sequences. Entropy with a value that is lower depicts the deterministic of the time sequence, while its randomness will be illustrated by a value that is higher. The findings of this scholarly work were articulated as a standard deviation. A value that was deemed to be significant is one that had a p value that was less than 0.05. In order to compare data amid the control groups, this study employed the Mann-Whitney Test [8].

TABLE I. CLINICAL ARIABLES

Clinical-data (N=400)	Healthy-Controls (N=100)	HF Patients (N=250)
Age in years	62 ± 6	65 ± 5
Male/Women	50/50	199/51
Freq of Electrocardiography (at rest)	71	29 ± 11
Ventricular premature-contractions per hour	3 ± 0.6	36 ± 3.9
Ejection of LV fraction	64 ± 5.3	30 ± 11
Wave	1.0 ± 0.3	07 ± 0.2
LVIDd	2.1 ± 0.6	3.1 ± 0.6

III. RESULT

Table I below lists the heart-rate as well as the clinical variables of the controls of health and sick individuals with heart failure.

The linear arithmetical HRV measures had no observable discrepancies. The sick individuals with heart failure had a comparatively higher fractal-dimension. Also, the results from this erudite work the existence of a cross-over phenomenon amid short-period scales that the DFA methodology estimated.

As Table II and Table III illustrates below, there was a momentous discrepancy amid long-suffering individuals with heart failure and the controls of health in short-period scales

TABLE II. THE VARIABLES OF HEART-RATE (NON-LINEAR & LINEAR DATA)

Variables	HEALTHY PTS		HF POINTS	
	X	Standard-Deviation	X	Standard-Deviation
R-R	640,26	48,17	621,49	56,43
Standard Deviation (R-R)	122,66	24,83	125,21	26, 12
Fractal Dimension D (R-R)	2,19	1,03	1,57	0,03
RR1	2,11	1,02	0,90	0,08
RR2	2,34	1,02	0,40	0,06
Approximate-Entropy	2,05	1,01	0,88	1,03

TABLE III. THE VARIABLES OF HEART-RATE (NON-LINEAR & LINEAR DATA)

Variables	HF Pts (after 12 months)		
	X	Standard-Deviation	X
R-R	617,24	42,43	NS
Standard Deviation (R-R)	123,23	24,25	NS
Fractal Dimension D (R-R)	1,37	0,01	***
RR1	1,08	0,076	***
RR2	1,33	0,02	NS
Approximate-Entropy	0,02	0,04	***

The findings apparently portray that the long-suffering individuals with heart-failure lost the fractal traits that was deemed to be normal and thus, augmented HRV promptness. On the other hand, those sick individuals with new-fangled psychoanalysis for heart-failure indicated gain in HRV.

Ultimately, from the results, it is clear that chaos theory has been widely applied in the analysis of the respiration in HRV analysis. In the beginning of HRV the nonlinear state is highly attributable to chaos theory.

This is because as seen in the methodologies above, the respiration rates for the sick-individuals with heart-failure differed significantly when slight changes were made. Less attention is usually paid on the impact of slight chang4es on the HRV [9]. It is also known that nonlinear HRV analysis using chaos theory is susceptible to respiratory influence [10].

IV. Discussion

From the above results, it is apparent that the measurement of fractal scaling exponent in short-time series, fractal dimensions and approximate entropy could give complimentary information on abnormal HR behavior in patients with heart failure, as well as the affirmative impact of the new-fangled treatments of the long-suffering individuals with heart failure [11].

Nonetheless, it is also known that nonlinear HRV analysis using chaos theory is susceptible to respiratory influence. From the reviewed studies, it is clear that if chaos theory is to be put into consideration, it is important to control respiratory influences because they affect HRV indices upon a slight change.

This is because the respiration rate greatly affects HRV in some instances when slight interruption is affected. Therefore, all these factors should be considered and the experiments of analysis of HRV using respiration should be carried in a controlled or factored out environment.

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