Identification of Premature Ventricular Contraction (PVC) of Electrocardiogram using Statistical Tools and Non-Linear Analysis

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Abstract

Non-linear analysis is a useful technique in a medical field specially in cardiac cases. Statistics tools Non-linear parameters have shown potentiality to the identification of diseases, especially in the analysis of biomedical signals like electrocardiogram (ECG). In this work, premature ventricular contraction (i.e abnormality) in ECG signals has been analysed using various non-linear techniques. First, the ECG signal is processed through a series of steps to extract the QRS complex. From this extracted feature, bit-to-bit interval (BBI) and instantaneous heart rate (IHR) have been calculated.

Index terms— electrocardiogram (ECG), premature ventricular contraction (PVC), instantaneous heart rate (IHR), standard deviation(SD), central tendency measure (CT

1 I. Introduction

he heart is the muscular organ that pumps the blood through the circulatory system by rhythmic contraction and dilation. In vertebrate there may be up to four chambers with two atria and two ventricles. Measuring the electrical activity of heart to show whether or not it is working normally and records the heart rhythm and activity on a moving strip of paper or a line on a screen, in a word that is called ECG. Electrocardiogram (ECG) is a wave that represents an electrical event in the heart, such as atrial depolarization, atrial repolarization, ventricular depolarization, ventricular repolarization, or transmission, and so on [1-4].

2 T a) Heart and ECG

The electric current generated by depolarization and repolarization of the atria and ventricles is detected by electrodes, it is amplified, displayed on an oscilloscope, recorded on ECG paper, or stored in memory. The electric current generated by atrial depolarization is recorded as the P wave, and that generated by ventricular depolarization is recorded as the Q, R, and S waves: the QRS complex. Atrial repolarization is recorded as the atrial T wave (Ta), and ventricular repolarization, as the ventricular T wave, or simply, the T wave. The sections of the ECG between the waves and complexes are called segments and intervals: the PR segment, the ST segment, the TP segment, the PR interval, the QT interval, and the R-R interval. When electrical activity of the heart is not being detected, the ECG is a straight, flat line -the isoelectric line or baseline.

3 II. Proposed Method

This work presents heart rate variability (HRV) analysis using some non-linear methods. The ECG signal to be analyzed is first processed [5] to extract the QRS complex. From that bit-to-bit interval (BBI) is calculated. From the BBI the instantaneous heart rate (IHR) is found. On this dataset of BBI and IHR, various non-linear parameters like Poincare plot analysis (PPA), central tendency measure (CTM), phase space portrait, detrended fluctuation analysis are determined. The result is very effective to distinguish the ECG signals between the healthy person and that of the ailing person.

4 a) Phase space portrait

Phase space or phase diagram is such a space in which every point describes two or more states of a system variable. The number of states [6] that can be displayed in phase space is called dimension or reconstruction dimension. It is usually symbolized by the letter d or E. From the given digitized data x(1), x(2), ?, x(n) of the IHR or BBI, a matrix A is obtained with its two columns given by x(1), x(2), ?, x(n-?) and x(1+ ?), x(2+ ?),.., x(n). Here ? is the time delay. The Phase space plot is constructed by plotting the data set with the time delay version of itself. The attribute of the reconstructed phase space plot depend on the choice of the value for ?. ? is measured through applying a autocorrelation function. Autocorrelation is a mathematical tool used frequently in signal processing for analyzing functions or series of values, such as time domain signals. Informally, it is a measure of how well a signal matches a with time-shifted version of itself, as a function of the amount of time shift. More precisely, it is the crosscorrelation of a signal with itself. Autocorrelation is useful for finding repeating patterns in a signal, such as determining the presence of a periodic signal which has been buried under noise, or identifying the missing fundamental frequency in a signal implied by its harmonic frequencies. ? is typically chosen as the time it takes the autocorrelation function of the data to decay to 1/e or the first minimum in the graph of the average mutual information. Here we used the two dimensional phase space portrait, i.e., d = 2.

Here in this project, phase space analysis has been used on IHR time series and the results are analyzed to see if any significant difference is found between normal and abnormal data series.

Following are the portraits obtained using phase space portrait on IHR. They are presented along with the IHR plot against each sample.

5 b) Poincare plot Analysis

The most commonly used non-linear method of analyzing heart rate variability is the Poincare plot. The Poincare plot analysis (PPA) [7] is a quantitative visual technique, whereby the shape of the plot is categorized into functional classes and provides detailed beat-tobeat information on the behaviour of the heart. Poincare plots are applied for a two-dimensional graphical and quantitative representation where ??? is plotted against ???+1.Most commonly, three indices are calculated from Poincare plots: the standard deviation of the shortterm RR-interval variability (SD1), the standard deviation of the long-term RR-interval variability (SD2) and the axes ratio (SD1/SD2) [8].

The standard deviation of the point's is perpendicular to the line-of identity denoted by SD1 describes short-term variability which is mainly caused by RSA. It can be shown that SD1 is related to the timedomain measure SDSD by, The standard Poincare plot can be considered to be of the first order. For the healthy heart, PPA shows a cigar-shaped cloud of points oriented along the line of identity.

In Poincare plot analysis here is the record of seven normal person's and seven abnormal person's ECG and analysis SD, **??**EAN Detrended Fluctuation Analysis is an interesting method for scaling the long-term autocorrelation of nonstationary signals **??**9] **??**10] **??**11][12]. It quantifies the complexity of signals using the fractal property. This method is a modified root mean square method for the random walk. Mean square distance of the signal from the local trend line is analyzed as a function of scale parameter. There is usually power-law dependence and interesting parameter is the exponent.

Detrended fluctuation analysis (DFA) measures the correlation within the signal. The correlation is extracted for different time scales. First, the RR interval time series is integrated,(?) = ? (??? ??=1 ? ??) ? ? ? ? ? k=1,?.N ? ..(2.3)

Where ??? ? ? ? is the average RR interval. Next, the integrated series is divided into segments of equal length n. Within each segment, a least squares line is fitted into the data. Let ?(?) denote these regression lines. Next the integrated series (?) is detrended by subtracting the local trend within each segment and the root-mean-square fluctuation of this integrated and detrended time series is calculated by, This computation is repeated over different segment lengths to yield the index (?) as a function of segment length n. Typically?(?) increases with segment length. A linear relationship on a double log graph indicates presence of fractal scaling and the fluctuations can be characterized by scaling exponent ? slope of the regression line relating log (?)to log n.

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?(?) = ? 1 ? ? [?(?) ? ? ? (?)] ? ?=1 2 (2.4)

In the DFA method, the fractal-like signal (1/f noise) results in exponent value ? =1.0, the white noise results in value 0.5, and the Brownian noise in value 1.5. White noise indicates a simulated uncorrelated random time series. The white noise is the value at one instant that does not correlate with any previous value, and the Brownian noise is the integration of the white noise. The 1/f noise can be interpreted as a "compromise" between the complete unpredictability of white noise and the much smoother "landscape" of Brownian noise.

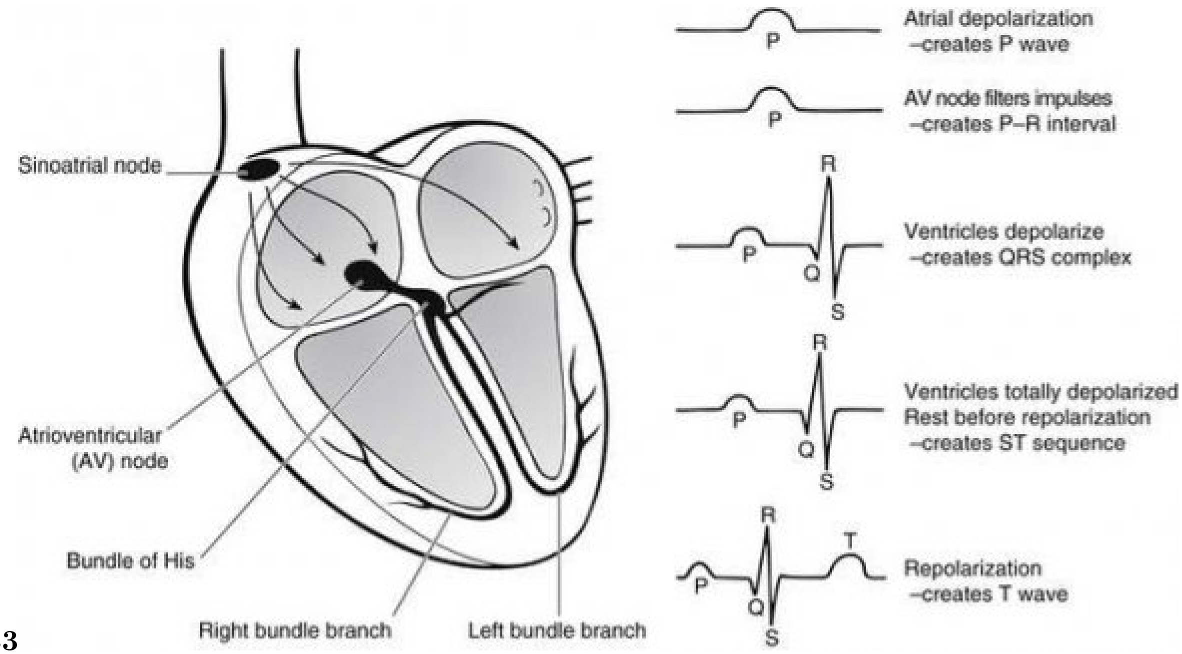
Here DFA1 & DFA2 for the normal patients and abnormal patients are taken and plotted them. (2.5)

Where, From the phase space plot for IHR, there lies significant difference between normal and abnormal rhythms. For the normal rhythm, there is normal attractor which forms a slope of almost 45 degree with the axes and there is slight dispersion around that attractor. For the abnormal rhythm, it is seen that their phase space portrait fill more space in the plane and there is random attractor present in the plot. Here from the figure it is seen that the all data of the normal patients is close to center. But for the abnormal patients the data scatter from the center as a result the area fill-up by the abnormal patients is more than the area fill-up by the normal patients. Using the DFA method it can be distinguished healthy from unhealthy subjects. Also can be determined which signal is more regular and less complex -useful for analyzing biomedical signals. It's concluded that using non-linear dynamics methods like DFA method is a quantitatively and qualitatively study of physiological signals. Here from the Figure 3.14 to 3.19 it is seen that central tendency is gradually increased with respect to the standard deviation than the normal patients. At the same way for the abnormal patients central tendency is not sharply increased with respect to standard deviation and the CTM values is always lower than 0.5 for abnormal patients. The normal patients's CTM value is similarly increased with respect to SD increase from 10% to 100 %. But for abnormal patients CTM values is increased gradually with respect to SD increase from 10% to 100. The normal patients's CTM value's is much higher than both abnormal patients's so it can be perfectly said that the normal patients's is much more healthy than other normal patients. ?(??) = 1, if r a a a a i i i i ? ? ? ? ? ? ? ? 5 . 0 2 1 2 1 2]) ( ) [((2.6) = 0, otherwise

7 Conclusion and Future Work

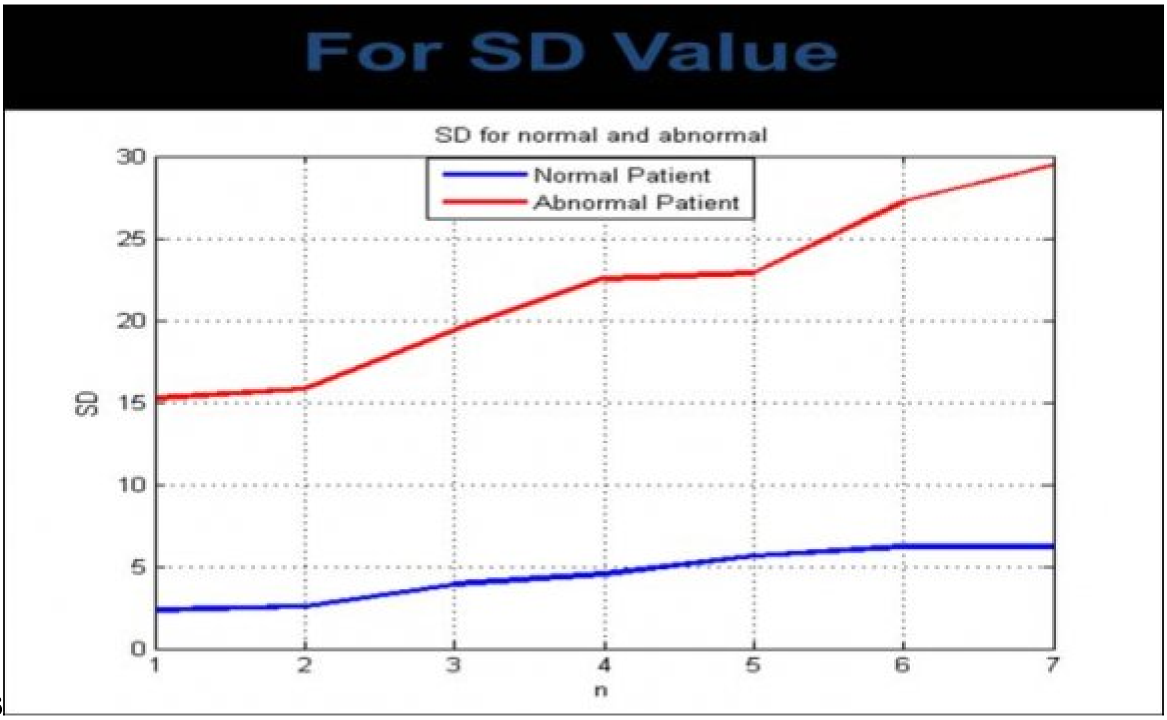
In this work PVC in ECG data set have been identified. The whole work is based on the fact that R-R intervals for normal rhythm data set tend to invariant and for the abnormal rhythm data set tend to vary a lot. This work describes the application of phase space portrait, Poincare Plot, DFA and CTM. Phase Space Portrait is a visible technique. From Poincare Plot a significant difference between normal and abnormal rhythm have been achieved. DFA determine the fluctuation of RR interval from the Slope. For normal rhythm value of CTM is more than the abnormal rhythm. Here clear difference for the normal and abnormal rhythm and high level of accuracy between them has been achieved. So it can be said that it is better to use CTM for classifying the ECG as normal or abnormal. In this paper abnormality of ECG signal have been detected specially in PVC cases. In future several frequency domain methods (i.e cross entropy analysis, Lyapunov Exponents, Support Vector Machine (SVM), Discrete Cosine Transform (DCT)) will be added to detect the abnormalities of heart. Future work may also include working with more number of abnormal records to generalize the detection of beat abnormality type. [1] [2] [3]

Figure 1:



33

Figure 2: Figure 3 Figure 3



36

Figure 3: Figure 3 . 6 :

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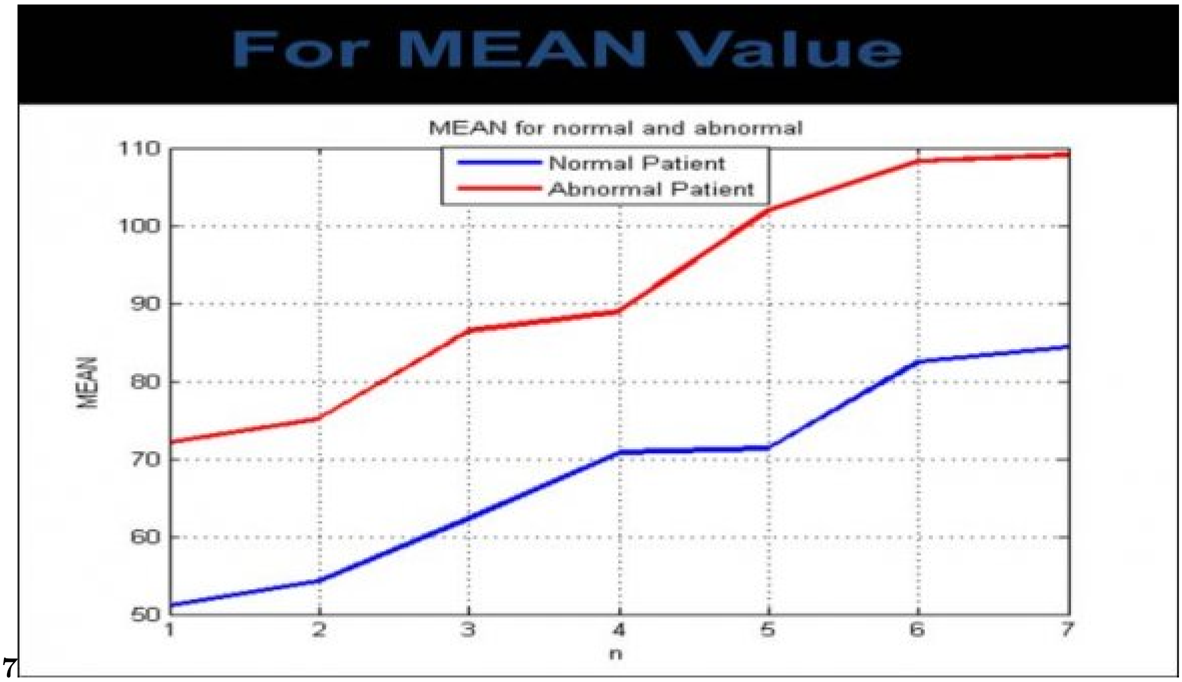

Figure 4: Figure 3 . 7 :

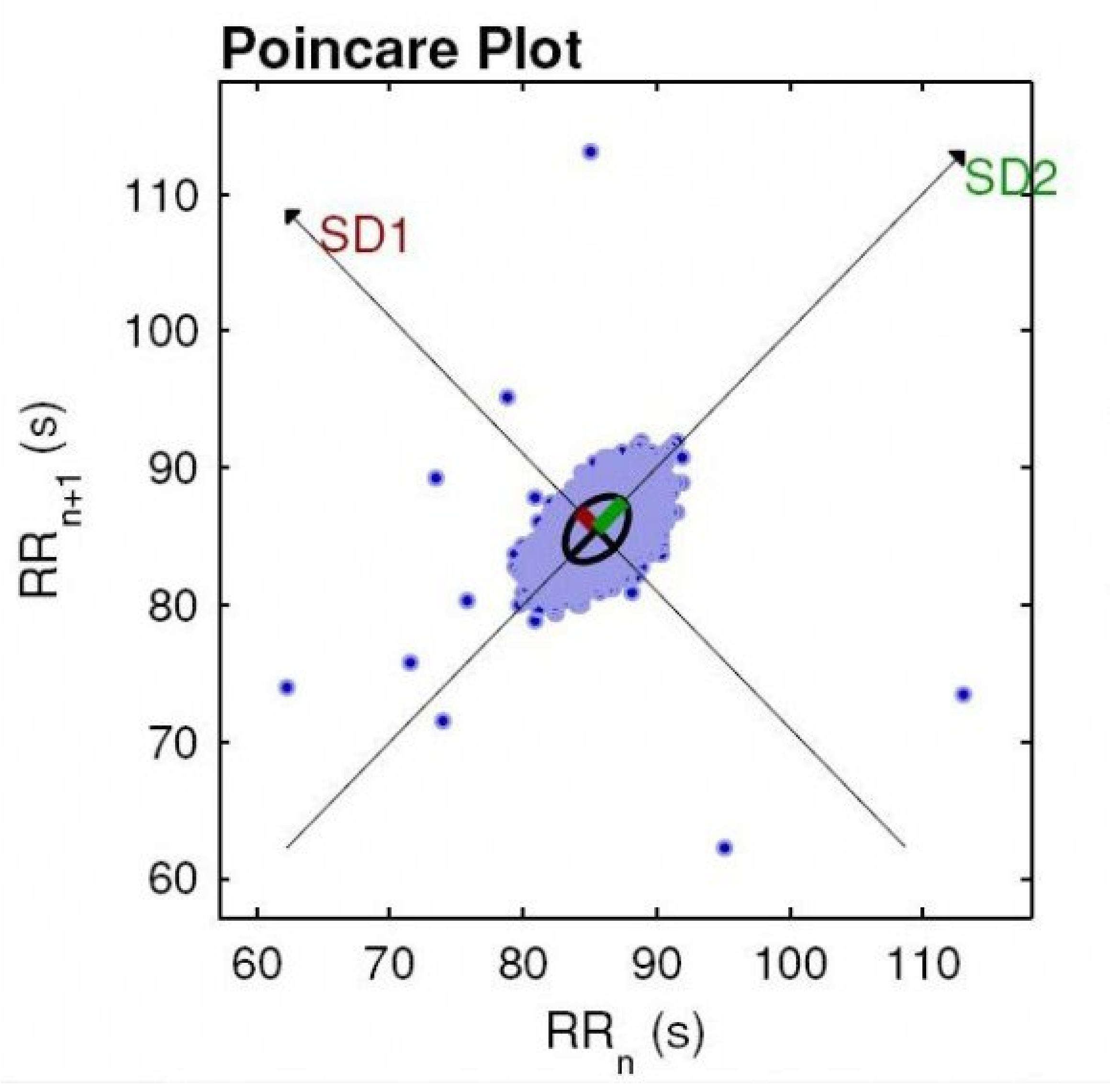
Poincare Plot
SD1
SD2
110
100
90
80
70
60
60
70
80
90
100
110
RR_{n+1} (s)
RR_n (s)

Figure 5: F

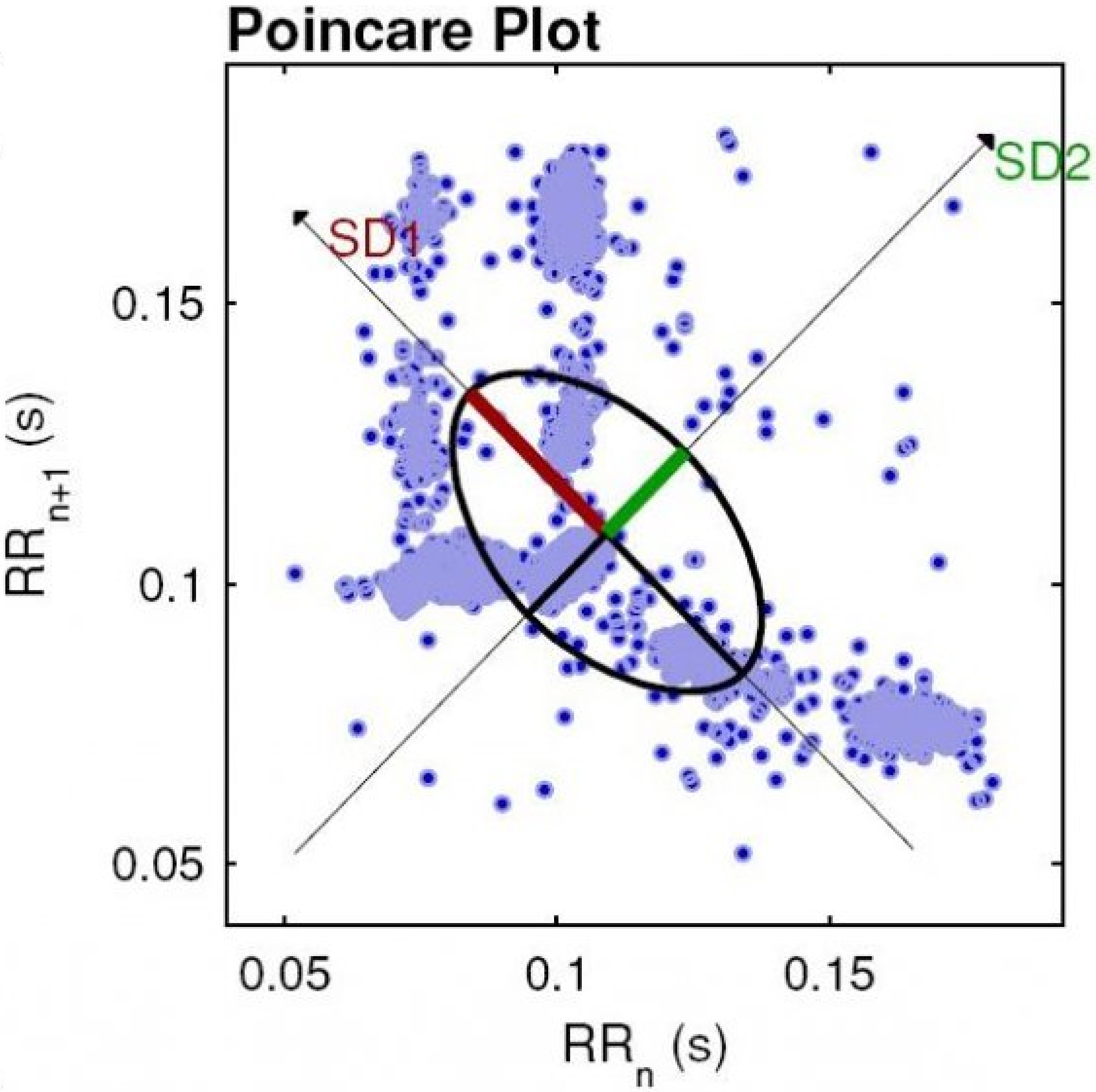

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Figure 6: Figure 3 .

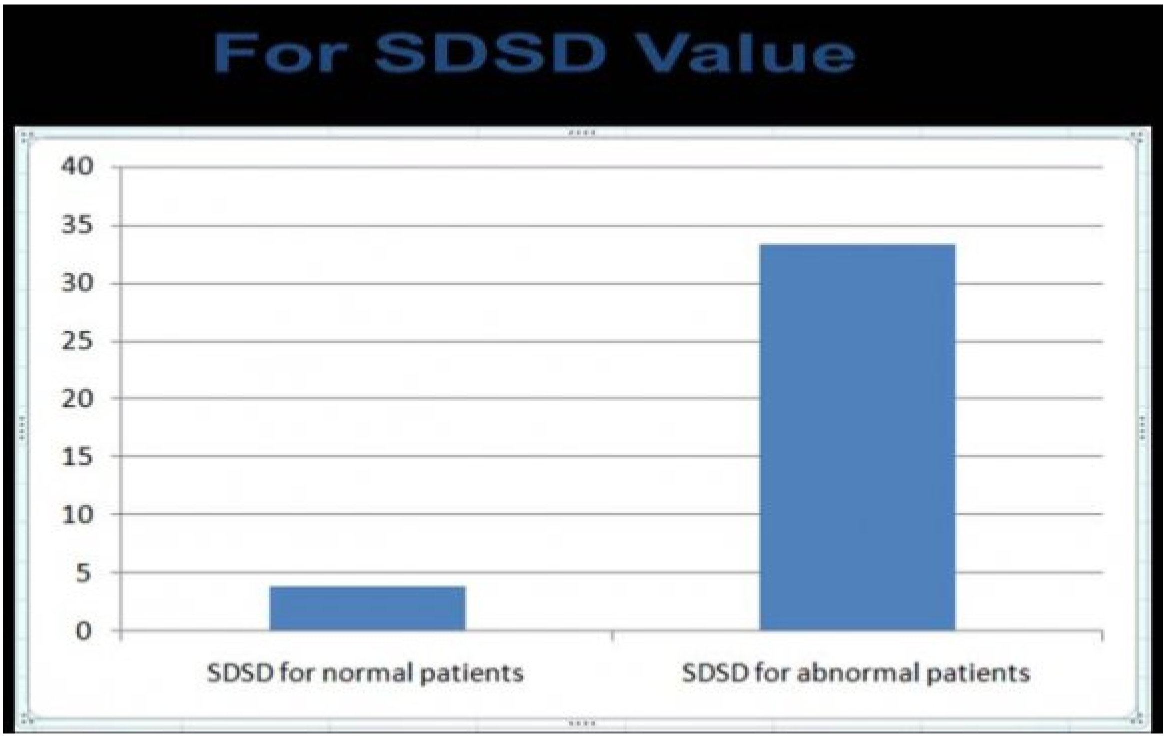

Figure 7: F

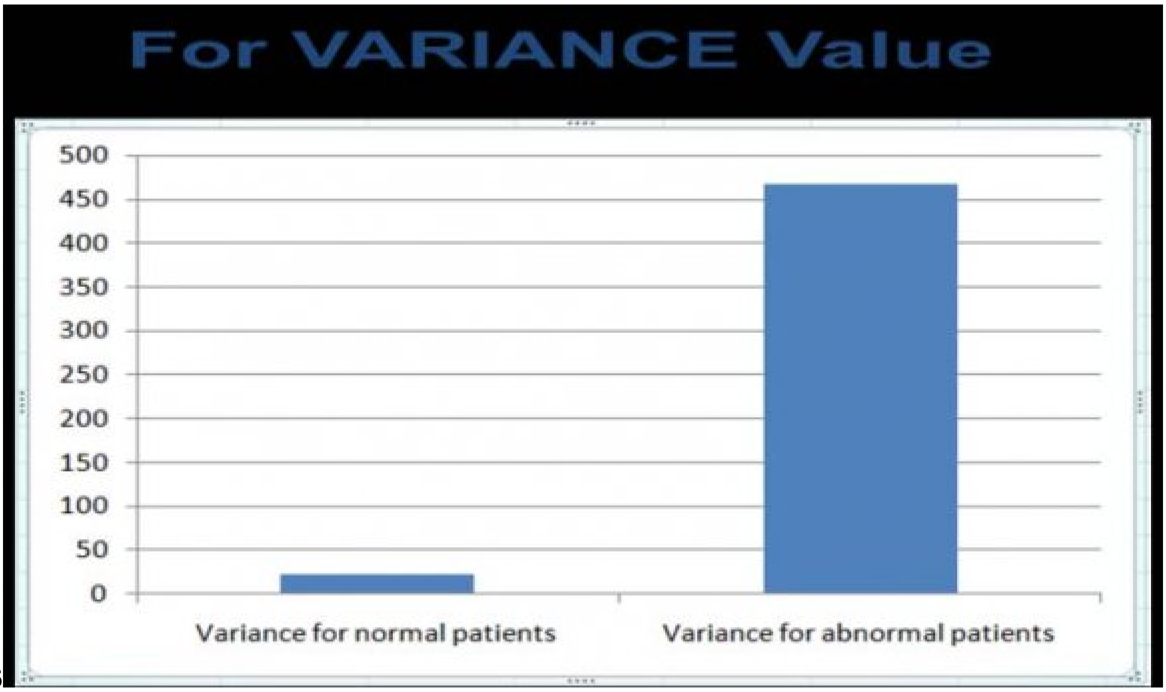

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Figure 8: Figure 3 . 2016 F©Year 2016 F

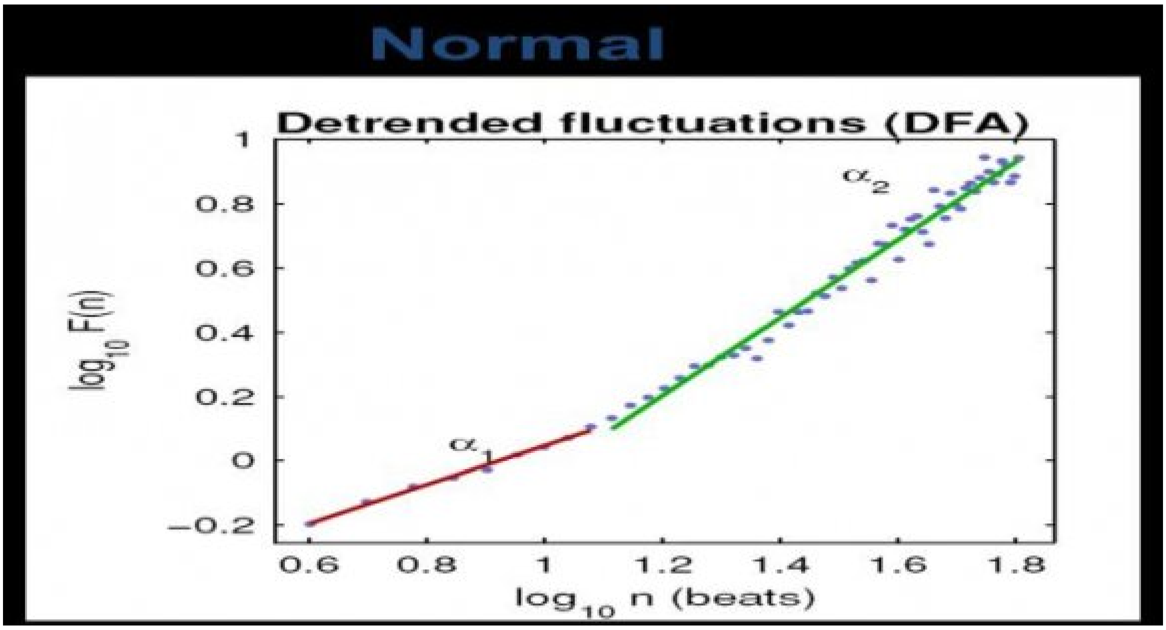

Figure 9:

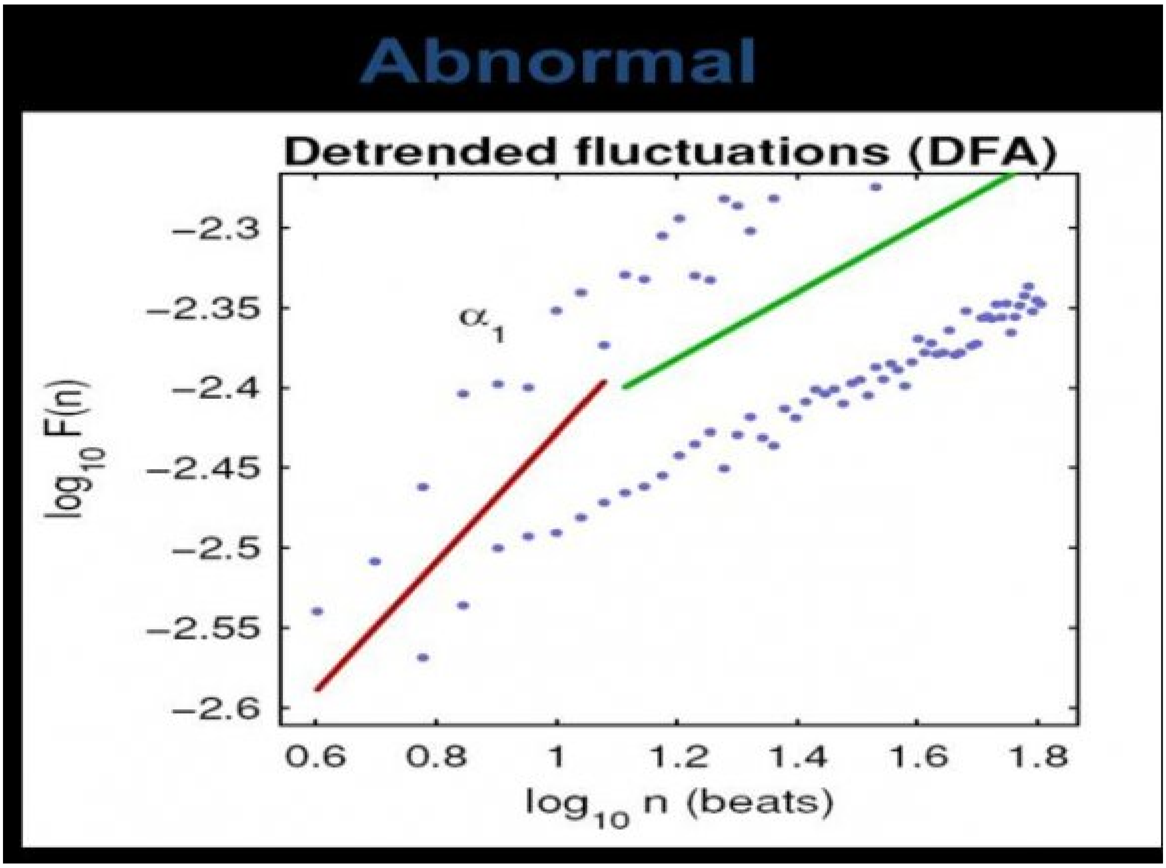

Figure 10:

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[Note: F © 2016 Global Journals Inc. (US)]

Figure 11: Table 2 .

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Figure 12: Table 2 .

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