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# A Novel Method by using Bipolar Merits for Mazhar-Eslam Variability frequency Algorithm to assess HRV for diagnostic, prognostic, and therapeutic determinations of Heart Diseases Diagnosis

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***Abstract-*** **In 1987, the variability of heart rate reported to have high prognostic value due to higher morbidity and mortality in patient suffering from myocardial disease. And this acts an indication for increasing the risk of cardiovascular events. One of the most important tests which used for assessing the function of the autonomic nervous system is the response of heart rate (HR) to the autonomic nervous system. Different research have demonstrated a link between Heart Rate Variability (HRV) and poor prognosis after heart attack, it approved that HRV measurements are widely effective for risk prediction of future cardiac events in heart attack survivors. For previous causes, HRV has a periodicity for monitoring and following up the cases. The present work introduces a novel method which reliable to analyze the linear and nonlinear behavior of heart complex wave variability, as the heart complex wave signal structure is not simply linear, but it also involves nonlinear contributions, and the two are correlated totally. In order to assess the use of the HRV as a versatile tool for heart disease diagnosis more ever introduce a declaration for the concept of the Lyapunov Exponent (LE) parameters to be used for HRV diagnosis and proposes a modified algorithm for more sensitive parameter computation. With giving a clear insight about the merits for using the bipolar in Mazhar-Eslam Variability Frequency (MVF).**

***Keyword:--- Bipolar, Diagnosis, Heart Rate Variability (HRV), Mazhar-Eslam Variability Frequency (MVF), Morbidity.***

## INTRODUCTION

RR- Variability is the other name for the variability of the heart rate (HRV); it defined in simple words as the changes in the duration of consecutive cardiac cycles. HRV evaluates the balancing act between (fight and flight) and the (rest and digest), i.e. sympathetic and parasympathetic nervous system [1]. Variety of linear, non-linear, periodical and aperiodical oscillation patterns are present in HR fluctuations. These patterns can be quantified in time domain using statistical analysis to calculate fluctuations in RR-intervals. Also, the HRV can be studied in frequency domain to analyze the energy content and its distribution within the R-R intervals [2, 3, 4]. Both time domain and frequency domain methods were studied assuming that HRV signals are linear [5], however these methods failed to fully quantify the dynamical structure of the HR signals and to derive sensitive diagnosis of HR diseases. In recent years, many researchers have investigated the prognostic implications of HRV in a variety of clinical populations. Evidence suggests that reduced HRV has prognostic significance for individuals with myocardial infarction, chronic heart failure, and diabetes mellitus [6, 7, 8, 9, 10, 11]; In contrast, a HR that is variable and responsive to demands is believed to bestow a survival advantage [12]. The fact that HRV is a result of both linear and nonlinear fluctuations opened new Perspectives as previous research was mostly restricted to linear techniques. Some situations or interventions can change the linear content of the variability, while leaving the nonlinear fluctuations intact. In addition, the reverse can happen: interventions. Which up till now have been believed to leave cardiovascular fluctuations intact based on observations with linear methods, can just as well modify the nonlinear fluctuations. This can be important in the development of new drugs or treatments for patients. The introduced new algorithm based on the Mazhar-Eslam algorithm considering whole cases of linear and nonlinear behavior for the HRV signal and pattern. It represents a Novel Method for verification the importance of using the modified Mazhar-Eslam algorithm as a most powerful indicator for HRV diagnosis.

## MAZHAR-ESLAM ALGORITHM MERITS

Mazhar-Eslam algorithm [13, 14] uses Discrete Wavelet Transform (DWT) considering the merits of DWT over that of FFT. Although the FFT has been studied extensively, there are still some desired properties that are not provided by FFT. There is some different points lead to selection DWT instead of FFT. The first one is hardness of FFT algorithm pruning. When the number of input points or output points is small comparing to the length of the DWT, a special technique called pruning is often used [15]. However, it is often required that those non-zero input data are grouped together. FFT pruning algorithms does not work well when the few non-zero inputs are randomly located. In other words, sparse signal does not give rise to faster algorithm. The other disadvantages of FFT are its speed and accuracy. All parts of FFT structure are one unit and they are in an equal importance. Thus, it is hard to decide which part of the FFT structure to omit when error occurring and the speed is crucial. In other words, the FFT is a single speed and single accuracy algorithm, which is not suitable for sensitive dependence (SED) cases. The other reason for not selecting FFT is that there is no built-in noise reduction capacity. Therefore, it is not useful to be used. According to the previous, the DWT is better than FFT especially in the SED calculations used in HRV, because each small variant in HRV indicates the important data and information. Thus, all variants in HRV should be calculated. Table 1 shows the different results of the normal case among Mazhar-Eslam, Wolf, and Rosenstein algorithms. From this table it is seen that, the Rosenstein algorithm has the lowest SED because of its quite high error (D = 51.72 %) comparing to the optimum, while the Wolf algorithm takes a computational place for SED (D = 1 %). However, the Mazhar-Eslam algorithm shows more sensitivity (D = 0.28 %) than Wolf algorithm as shown in figure 1.The bar diagrams in figure 2 shows the percentage deviation of the three algorithms. From this figure it is seen that the Mazhar-Eslam algorithm gives the best result as it has the lowest percentage deviation (D = 14). At the same time, when calculating the variance to determine the accurate and best method, Mazhar-Eslam algorithm gives the best value. Figure 3 shows the bar diagram of the variance for normal control case using the HRV for Wolf, and Mazhar-Eslam algorithms. It is clear that the Mazhar-Eslam algorithm is more powerful and accurate than Wolf, because its variance better than Wolf by 0.0036. This result comes because the Mazhar-Eslam considers all the variability mean frequencies $\overline{\Omega_M}$s unlike the Wolf method as it takes only the largest. Each interval of the HRV needs to be

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well monitored and taken into account because the variant in HRV is indication of cases.

**Table1 Norman case Results**

| Method / Parameter | Optimum | Rosenstein | Wolf | Mazhar-Eslam |
|---|---|---|---|---|
| $\Omega_M$ | 0.500000 | 0.758600 | 0.505000 | 0.498600 |
| D | 0.00000 | 0.258600 | 0.005000 | 0.001400 |
| D% | 0.000000 | 51.720000 | 1.000000 | 0.280000 |
| Var | 0.250000 | 0.058274 | 0.245025 | 0.248602 |

From the bar diagram in figure 3 it is seen that the Mazahar-Eslam algorithm is most useful and sensitive comparing to Wolf and Rosenstein algorithms.

## DISCUSSION THE NOVEL APPROACH

The MVF "$\Omega_M$" divergence of initially nearby trajectories in state-space coupled with folding of trajectories. Therefore, the existence of a positive LVF ($\Omega_M > 0$) for almost all initial conditions in a bounded dynamical system is the widely used definition of deterministic chaos. To discriminate between chaotic dynamics and periodic signals, the MVF $\Omega_M$ are often used. The trajectories of chaotic signals in state-space follow typical patterns. Closely spaced trajectories converge and diverge exponentially, relative to each other. *A negative MVF* ($\Omega_M < 0$) means that the orbit attracts to a stable fixed point or stable periodic orbit. Negative MVFs are characteristic of dissipative or non-conservative systems. Such systems exhibit asymptotic stability. The more negative the MVF, the greater the stability. Super stable fixed points and super stable periodic points have a MVF tends to infinity i.e. $\Omega_M = -\infty$. Generally, the HRV for healthy person has some periodicity. While the HRV for the patient is usually a periodic stochastic signal. Thus, for more periodic variability signal (i.e. stochastic signal) the case will stay in the same status and indicates to utmost important information. Subsequently, the HRV stochastic signal periodicity should be studied and analyzed for prediction. The MVF is suitable and sensitive tool for predicting the HRV, therefore it is used to predict and verify the importance of HRV stochastic periodicity. Consequently, to study the stochastic periodicity and variation in the HRV the negative and positive MVFs $\Omega_M$s should be taken in account, as the positive part indicates case status and the negative part indicates the stability and periodicity. This explains the necessity to consider both polarities (positive and negative) of the MVF, (i.e. $\Omega_M > 0$ and$\Omega_M < 0$). Thus, a new approach Bipolar Mazhar-Eslam Variability Frequency method is introduced. Theoretically speaking, the introduced Bipolar Mazhar-Eslam Variability Frequency calculations for the ideal HRV that comes from ideal Electrocardiograph (ECG) is 0.5 for positive MVF, which indicates a healthiest case and $-1$ for the negative MVF that indicates for more HRV stochastic periodic signal. Thence, the difference of the introduced Bipolar Mazhar-Eslam Variability Frequency $\overline{\Omega_M}$ is -0.5, and around this value, the case is healthy. For the control case, the introduced Bipolar Mazhar-Eslam $MVF_B$ $\overline{\Omega_M}$ is 0.4986 and – 0.9832. The difference of the Bipolar MVF for normal control case is $-$ 0.4846, which is very close to $-$ 0.5. Consequently, the introduced Bipolar Mazhar-Eslam Variability Frequency $MVF_B$ plays important role in monitoring, predicting and diagnosing the HRV stochastic signal. The Bipolar Mazhar-Eslam $MVF_B$ has ability to monitor and follow up the patient case. It shows the disease by the positive $MVF_B$ ($\overline{\Omega_M} > 0$) part and shows the periodicity by the negative $MVF_B$ ($\overline{\Omega_M} < 0$) part. To verify and show the benefits of the $MVF_B$ some critical diseases data from MIT-BIH are used. The table 2 discusses the introduced Bipolar

Mazhar-Eslam Variability Frequency $MVF_B$ in many different cases from MIT-BIH and compares it with Mazhar-Eslam, Wolf, and Rosenstein algorithms results.

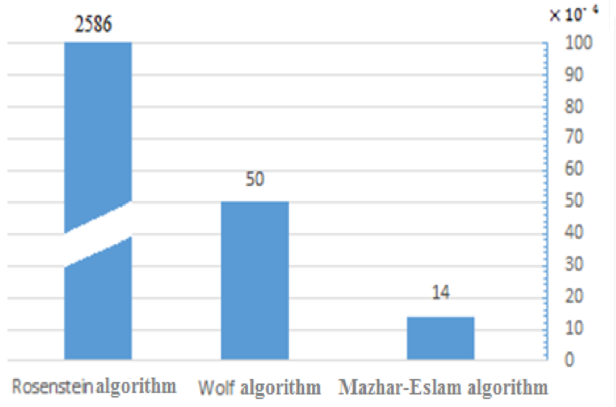


**Figure 1 Deviation in Normal case.**

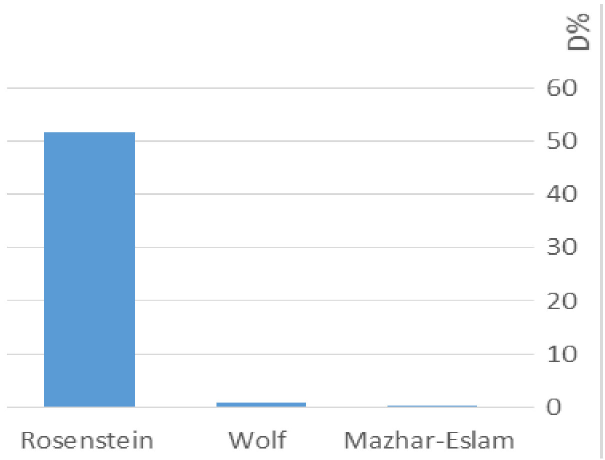


**Figure 2 normal case deviations in Percent.**

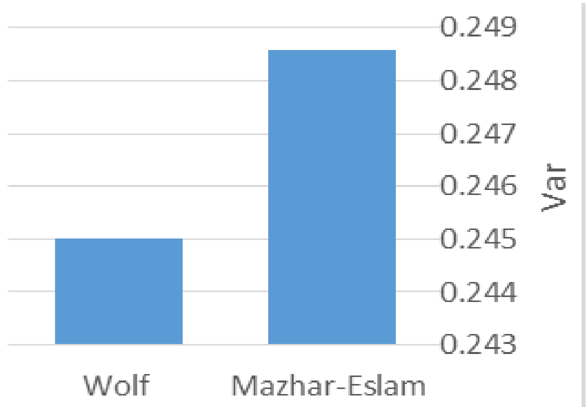


**Figure 3 Variance of Wolf and Mazhar-Eslam**

**Table 2 LVF results of different methods using normal case and the MIT-BIH sample cases.**

| Parameter | | MVF | | |
|---|---|---|---|---|
| S. No | Method/ Case | Rosenstein | Wolf | Mazhar-Eslam |
| 1 | Normal | 0.7586 (HF) | 0.505 (HF) | 0.4986 (HF) |
| 2 | 101 | 0.2500 (HF) | 0.1700 (HF) | 0.0830 (LF) |
| 3 | 102 | 0.1600 (HF) | 0.1300 (LF) | 0.0530 (VLF) |
| 4 | 104 | 0.2100 (HF) | 0.1300 (LF) | 0.0700 (LF) |
| 5 | 106 | 0.2300 (HF) | 0.1500 (LF) | 0.0770 (LF) |
| 6 | 107 | 0.2000 (HF) | 0.1300 (LF) | 0.0667 (LF) |
| 7 | 109 | 0.2200 (HF) | 0.1400 (LF) | 0.0733 (LF) |
| 8 | 111 | 0.2400 (HF) | 0.1600 (HF) | 0.0800 (LF) |
| 9 | 112 | 0.2400 (HF) | 0.1700 (HF) | 0.0800 (LF) |
| 10 | 115 | 0.2800 (HF) | 0.1700 (HF) | 0.0930 (LF) |
| 11 | 117 | 0.2300 (HF) | 0.1600 (HF) | 0.0770 (LF) |
| 12 | 118 | 0.2500 (HF) | 0.1600 (HF) | 0.0833 (LF) |
| 13 | 119 | 0.2700 (HF) | 0.1700 (HF) | 0.0900 (LF) |
| 14 | 121 | 0.2500 (HF) | 0.1600 (HF) | 0.0840 (LF) |
| 15 | 122 | 0.2300 (HF) | 0.1600 (HF) | 0.0770 (LF) |
| 16 | 123 | 0.2300 (HF) | 0.1500 (LF) | 0.0770 (LF) |
| 17 | 124 | 0.2500 (HF) | 0.1700 (HF) | 0.0840 (LF) |
| 18 | 200 | 0.2300 (HF) | 0.1500 (LF) | 0.0770 (LF) |
| 19 | 203 | 0.2300 (HF) | 0.1500 (LF) | 0.0770 (LF) |
| 20 | 212 | 0.2100 (HF) | 0.1400 (LF) | 0.0700 (LF) |
| 21 | 221 | 0.2100 (HF) | 0.1400 (LF) | 0.0700 (LF) |
| 22 | 230 | 0.2100 (HF) | 0.1400 (LF) | 0.0700 (LF) |
| 23 | 231 | 0.2200 (HF) | 0.1500 (LF) | 0.0740 (LF) |


## MVF PERIODICITY

To study and analyze table 2, it be order related to field study. The results of the next proposal is based on studding of fields is periodicity of MVF algorithms.

## STUDY OF PERIODICITY

An important studying for results in the table 2 is the periodicity phenomena. The periodicity is utmost important for monitoring patient cases. Table 3 discusses this phenomenon. The periodicity comes from unchanged values in R-R complex for more than one interval. The case will be stable and healthy for more unchanged HRV. The next table 3 shows the periodicity phenomena benefit in the introduced Bipolar Mazhar-Eslam MVF. As the more negative value of $\Omega_M$ indicates to more periodic variability. The low value of Mazhar-Eslam MVF $\overline{\Omega_M}$ indicates to more patient and critical case and vice versa, higher value of Mazhar-Eslam MVF $\overline{\Omega_M}$ indicates to healthier. Thus, when studying the results in the negative part of the introduced Bipolar Mazhar-Eslam Variability Frequency $MVF_B$ ($\overline{\Omega_M}$) , the value of $\overline{\Omega_M}$ for critical case is close to zero, and it is mean there is no periodicity in this case and it refers to unstable case like case 102. The $\overline{\Omega_M}$ tends to more negative result value in negative part of the introduced Bipolar Mazhar-Eslam Variability Frequency $MVF_B$ for more stable, healthier and more periodic signal. This phenomenon of periodicity verify the accuracy of the Mazhar-Eslam algorithm for MVF compare to Wolf and Rosenstein algorithms and gives the new chapter for monitoring and following up the cases by using the introduced Bipolar Mazhar-Eslam Variability Frequency $MVF_B$. The next figures 4, 5 present these criteria.

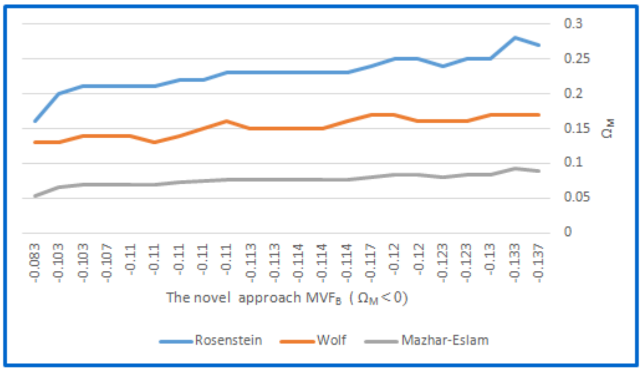


**Figure 4 MVF algorithms sensitivity by periodicity criterion**

The previous figures 6, 7 show how the Mazhar-Eslam algorithm MVF is the most accurate and sensitive. As mentioned before, the negative part of the Novel approach Bipolar Mazhar-Eslam $MVF_B$ indicates to periodicity.

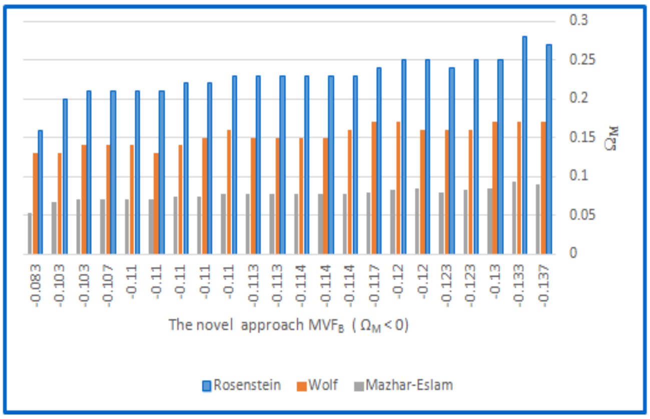


**Figure 5 bar diagram for MVF algorithms sensitivity by periodicity criterion.**

The figure 6, 7 is used to compare between Lyapunov algorithms and shows which the most accurate and sensitive on. Depending on the graphs in the figures 6, 7 the Mazhar-Eslam algorithm has more linearity in periodicity than Wolf and Rosenstein algorithms that because it has more periodic sensitivity. This observation leads to the Mazhar-Eslam algorithm is more sensitive beside its accuracy. The Wolf comes after Mazhar-Eslam algorithm in sensitivity accuracy perfection for HRV, and the Rosenstein is the worst one. Figure 6 presents a new chapter of chart for assessing and determining the periodicity. Mazhar-Eslam chart measure the algorithm periodicity by how the circulation of algorithm is Mazhar-Eslam algorithm success to reach the most circulation for MVF algorithms because it's sensitive and periodicity results unlike other algorithms Wolf and Rosenstein. The Wolf takes the second place in the periodicity as shown in figure 6. The Rosenstein is the lowest periodic sensitive algorithm. Thus, the Mazhar-Eslam algorithm is to be immense recommended algorithm for MVF as a tool for HRV prediction.

## $MVF_B$ DIFFERENCE (SPAN)

To study and analyze table 2, it be order related to field study. The results of the next proposal is based on studding of fields is the introduced Bipolar

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Mazhar-Eslam Variability Frequency $MVF_B$ difference (Span).

**Table 3 MVF periodicity phenomenon**

| Method / Case | MVF: Rosenstein | MVF: Wolf | MVF: Mazhar-Eslam | Bipolar: Λ > 0 | Bipolar: Λ < 0 |
|---|---|---|---|---|---|
| Normal | 0.7586 | 0.505 | 0.4986 | 0.4986 | -0.9832 |
| 119 | 0.2700 | 0.1700 | 0.0900 | 0.0900 | -0.1370 |
| 115 | 0.2800 | 0.1700 | 0.0930 | 0.0930 | -0.1330 |
| 124 | 0.2500 | 0.1700 | 0.0840 | 0.0840 | -0.1300 |
| 118 | 0.2500 | 0.1600 | 0.0833 | 0.0833 | -0.1230 |
| 111 | 0.2400 | 0.1600 | 0.0800 | 0.0800 | -0.1230 |
| 121 | 0.2500 | 0.1600 | 0.0840 | 0.0840 | -0.1200 |
| 101 | 0.2500 | 0.1700 | 0.0830 | 0.0830 | -0.1200 |
| 112 | 0.2400 | 0.1700 | 0.0800 | 0.0800 | -0.1170 |
| 122 | 0.2300 | 0.1600 | 0.0770 | 0.0770 | -0.1140 |
| 203 | 0.2300 | 0.1500 | 0.0770 | 0.0770 | -0.1140 |
| 123 | 0.2300 | 0.1500 | 0.0770 | 0.0770 | -0.1140 |
| 106 | 0.2300 | 0.1500 | 0.0770 | 0.0770 | -0.1130 |
| 200 | 0.2300 | 0.1500 | 0.0770 | 0.0770 | -0.1130 |
| 117 | 0.2300 | 0.1600 | 0.0770 | 0.0770 | -0.1100 |
| 231 | 0.2200 | 0.1500 | 0.0740 | 0.0740 | -0.1100 |
| 109 | 0.2200 | 0.1400 | 0.0733 | 0.0733 | -0.1100 |
| 104 | 0.2100 | 0.1300 | 0.0700 | 0.0700 | -0.1100 |
| 212 | 0.2100 | 0.1400 | 0.0700 | 0.0700 | -0.1100 |
| 221 | 0.2100 | 0.1400 | 0.0700 | 0.0700 | -0.1070 |
| 230 | 0.2100 | 0.1400 | 0.0700 | 0.0700 | -0.1030 |
| 107 | 0.2000 | 0.1300 | 0.0667 | 0.0667 | -0.1030 |
| 102 | 0.1600 | 0.1300 | 0.0530 | 0.0530 | -0.0830 |

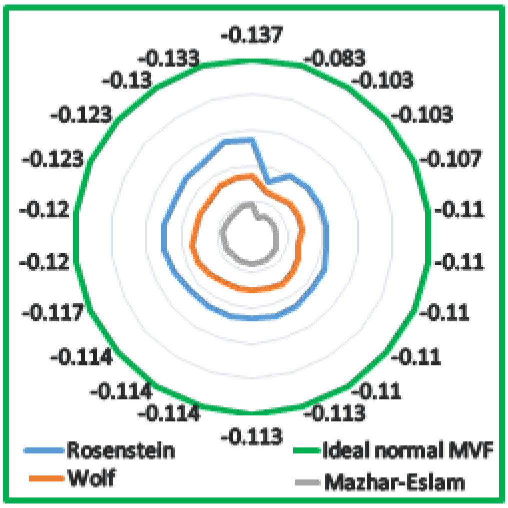


**Figure 6 Mazhar-Eslam charts to assess the periodicity criterion MVF algorithms sensitivity.**

## STUDY OF DIFFERENCE (SPAN)

Another important studying for results in the table 2 is the difference of the introduced Bipolar Mazhar-Eslam MVF. This different of the introduced Bipolar Mazhar-Eslam MVF has ability to define the ECG matter. Table 4 put the results in six groups regardless the normal control case. The first group is normal ECG and contains cases 101, 112, 122, 123, 203, 221, and 109 and ordered ascending related to difference and normality. The second group is pacing ECG and it contains cases 111, 115, 104, 212, and 118.

**Table 4 Span of the introduced Bipolar Mazhar-Eslam MVF**

| Method / Case | MVF: Rosenstein | MVF: Wolf | MVF: Mazhar-Eslam | Bipolar: Λ > 0 | Bipolar: Λ < 0 | Bipolar: Difference |
|---|---|---|---|---|---|---|
| Control | 0.7586 | 0.505 | 0.4986 | 0.4986 | -0.9832 | -0.4846 |
| 119 | 0.2700 | 0.1700 | 0.0900 | 0.0900 | -0.1370 | -0.0470 |
| 124 | 0.2500 | 0.1700 | 0.0840 | 0.0840 | -0.1300 | -0.0460 |
| 111 | 0.2400 | 0.1600 | 0.0800 | 0.0800 | -0.1230 | -0.0430 |
| 115 | 0.2800 | 0.1700 | 0.0930 | 0.0930 | -0.1330 | -0.0400 |
| 104 | 0.2100 | 0.1300 | 0.0700 | 0.0700 | -0.1100 | -0.0400 |
| 212 | 0.2100 | 0.1400 | 0.0700 | 0.0700 | -0.1100 | -0.0400 |
| 118 | 0.2500 | 0.1600 | 0.0833 | 0.0833 | -0.1230 | -0.0397 |
| 101 | 0.2500 | 0.1700 | 0.0830 | 0.0830 | -0.1200 | -0.0370 |
| 112 | 0.2400 | 0.1700 | 0.0800 | 0.0800 | -0.1170 | -0.0370 |
| 122 | 0.2300 | 0.1600 | 0.0770 | 0.0770 | -0.1140 | -0.0370 |
| 123 | 0.2300 | 0.1500 | 0.0770 | 0.0770 | -0.1140 | -0.0370 |
| 203 | 0.2300 | 0.1500 | 0.0770 | 0.0770 | -0.1140 | -0.0370 |
| 221 | 0.2100 | 0.1400 | 0.0700 | 0.0700 | -0.1070 | -0.0370 |
| 109 | 0.2200 | 0.1400 | 0.0733 | 0.0733 | -0.1100 | -0.0367 |
| 107 | 0.2000 | 0.1300 | 0.0667 | 0.0667 | -0.1030 | -0.0363 |
| 121 | 0.2500 | 0.1600 | 0.0840 | 0.0840 | -0.1200 | -0.0360 |
| 200 | 0.2300 | 0.1500 | 0.0770 | 0.0770 | -0.1130 | -0.0360 |
| 106 | 0.2300 | 0.1500 | 0.0770 | 0.0770 | -0.1130 | -0.0360 |
| 231 | 0.2200 | 0.1500 | 0.0740 | 0.0740 | -0.1100 | -0.0360 |
| 117 | 0.2300 | 0.1600 | 0.0770 | 0.0770 | -0.1100 | -0.0330 |
| 230 | 0.2100 | 0.1400 | 0.0700 | 0.0700 | -0.1030 | -0.0330 |
| 102 | 0.1600 | 0.1300 | 0.0530 | 0.0530 | -0.0830 | -0.0300 |

The third group is ECG with bundle premature ventricular and it contains cases 107, 121, 200, 106, and 231. The fourth group is ECG with bundle branch block and it contains 119 and 124. The fifth group is bigeminy ECG and it contains 117 and 230. The last case 102 is ECG with sustained ventricular tachycardia. Thence, the Difference can classify the ECG.

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## CONCLUSION

Heart Rate Variability (HRV) is reported in several cardio logical and non-cardio logical diseases. Also, it has a prognostic value and is therefore very important in modelling the cardiac risk. HRV is stochastic signal that remains highly controversial. In order to have utmost importance, HRV needs a sensitive tool to analyze it. It is concluded that Mazhar-Eslam variability mean frequency, is a better quantitative measure of sensitivity than others. The Rosenstein algorithm provided less sensitive $MVF$ estimates than the Wolf algorithm to capture differences in local dynamic stability from small gait data sets. The data supported the idea that this latter outcome results from the ability and inability of the Wolf algorithm and Rosenstein algorithm, respectively, to estimate adequately MVF of attractors with an important rate of convergence as those in gait. Therefore, the Mazhar-Eslam algorithm appears to be more appropriate to evaluate local dynamic stability from small gait data sets like HRV. Increase in the size of data set has been shown to make the results of the Mazhar-Eslam algorithm more suitable, although other means as increasing the sample size might have a similar effect. The Mazhar-Eslam algorithm takes the same strategy of Rosenstein method for initial step to calculate the lag and mean period, but it uses Discrete Wavelet Transform (DWT) instead of Fats Fourier Transform (FFT) unlike Rosenstein. After that, it completes steps of calculating $\Omega_M$ as Wolf method. The Mazhar-Eslam method cares of all variants especially the small ones like that are in HRV. These variants may contain many important data to diagnose diseases as R-R interval has many variants. Thus, the Mazhar-Eslam algorithm for MVF $\overline{\Omega_M}$ takes all of $\Omega_M$s. That leads it to be robust predictor and that appear in different results among Mazhar-Eslam, Wolf, and Rosenstein. The Mazhar-Eslam algorithm represents a new idea for HRV prediction. It contains a positive part for HRV as it is stochastic signal and the negative part for periodicity. The periodicity phenomenon supports to follow-up the cases and it has the ability of monitoring. Mazhar-Eslam algorithm takes the best place in periodicity sensitivity and Wolf algorithm is the second one. The Rosenstein algorithm is the worst algorithm for MVF in sensitivity and periodicity. Thus, Mazhar-Eslam algorithm MVF $\overline{\Omega_M}$ is the best MVF algorithm for HRV predication.

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## Author's Profile

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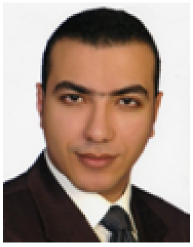

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