Prediction of Ventricular Tachycardia using Nonlinear Features of Heart Rate Variability Signal such as Poincare Plot, Approximate and Sample Entropy, Recurrence Plot

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Abstract

In the ventricular tachycardia (VT), due to improper contractions of the ventricles and excessive increase in heart rate, very little blood is released from the heart, and if not treated promptly, it can lead to the death of the patient. The occurrence of VT and its timely diagnosis are signs of heart rate changes (HRV) that are helpful in detecting it. But before it happens, it's not easy to find such symptoms, and this becomes even more acute when it comes to predicting the time to go backwards. The utilized data are taken from Physionet database The data studied in this article is data available in the MVTDB database of physionet, which includes 212 records from the patient group with VT and the control group. In this study, an algorithm was proposed to predict VT based on the extraction of nonlinear characteristics of the HRV signal. To evaluate the effectiveness of the features, t-test analysis was used and PCA algorithm was used to reduce the dimensions of the feature. The features that have been given to predict separation between two healthy and patient classes are given to the Artificial Neural Network(ANN). In this study, three different modes were studied to examine the values of the characteristics and how changes in their values at various time intervals could be a warning to the attack, and the results of all three modes were compared together and finally, with significant changes The values of the properties in the range of 130 to 10 seconds before the start of the attack, VT prediction with accuracy of 94.28% in this interval.

Keywords: Prediction ,Heart Rate Variability, ventricular tachycardia , Artifical Neural Network

1 introduction

Heart disease is one of the main causes of death in the world. And about 80% of sudden cardiac death occurs due to Ventricular tachyarrhythmia such as VT. In a person with a VT, a set of ventricular contractions are generated from a point within the ventricles. And the heart rate rises from 100 beats per minute to 250 beats per minute. And the outflow of the heart is severely disrupted. VT may also cause sudden arrest if not treated immediately. VT is usually dangerous for two reasons: Firstly, this arrhythmia is usually caused only when there is significant damage to the ventricles. Alternatively, this arrhythmia usually causes the fatal state of ventricular fibrillation, because the ventricle muscle quickly stimulates . Therefore, the use of an appropriate method to predict this arrhythmia in the right time provides the opportunity to provide emergency and medical treatment. One of the ways to examine heart activity and differentiate different types of heart failure from one another is to measure and analyze changes in heart rate with time. This signal is less sensitive to noise, and due to its nonlinear nature, nonlinear parameters Additionally, use time and

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frequency parameters which increases the classification accuracy. Also, in the field of prediction of VT arrhythmia, studies such as prediction using the 50-ms threshold for the SDNN feature and comparing the HRV signal between the state of health and the patient's individual state(1), the VT prediction algorithm by examining the changes in the wave T and the QT interval before Early ventricular contraction was calculated by computing the two characteristics of QTVI and TeVI and their differences before and after Premature Ventricular Complex arrhythmia(PVC) in a group with both PVC and VT arrhythmias, and a group of patients with PVC(2), as well as prediction using morphological characteristics of the signal and support vector machine(SVM)(3).In this study, we tried to compare the changes of the linear and nonlinear characteristics of the HRV signal between the two healthy groups and the patient and the changes in three different time intervals, the prediction is done at the right time.

2 The proposed algorithm

In this paper, an algorithm for predicting VTA is used by analyzing the parameters extracted from the HRV signal and the neural network learning(4). In Figure 1, the proposed algorithm is shown.

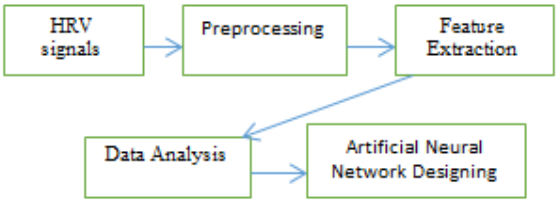

Figure1 general flochart of the method used in this study

3 Data

RR interval time series were obtained from the PhysioNet's Spontaneous Ventricular Tachyarrhythmia Database Version 1.0 from Medtronic, This data contains 106 pairs of RR interval time series, recorded by implanted cardioverter defibrillators in patients. Each series contains between 986 and 1022 RR intervals. ICD continuously digitizes and analyzes the patient's electrogram (EGM). R-waves are detected in the EGM with an auto-adjusting sense amplifier. A series of each pair contains one part of the VT and the Pre-VT series is called.in this group each recorded signal includes a complete transition from normal to the onset of VT. . As a result, the end of each of the recorded signals is the place where the occurrence of VT occurs. And the other series is an example of the natural rhythm of the same patients in non-invasive conditions VT (usually sinusoidal) and is called the MR series.

4 Preprocessing

4-1 Selection of sample RR intervals from HRV signals in the pre-VT group:

In this group, two samples were taken at a distance of RR of HRV signal on each signal. . First, 10 seconds after the onset of the ventricular tachycardia, we will go back and then select a time interval of one minute, which begins 70 seconds before the VT attack and it is completed 10 seconds before the VT attack (close to the attack). The selected range is shown in Figure 2.

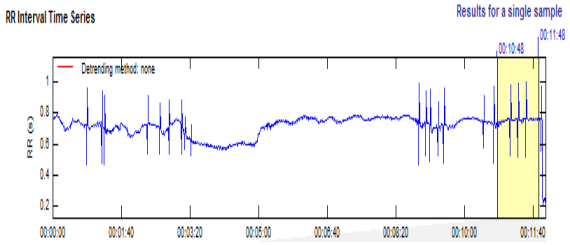

Figure 2 separating a one-minute of RR interval close to the start time of the VT attack on the HRV signal

Then, on each signal, a one-minute interval ranged from 130 to 70 seconds before the start of the VT attack was selected(distances from the attack).The selected range is shown in Figure 3.

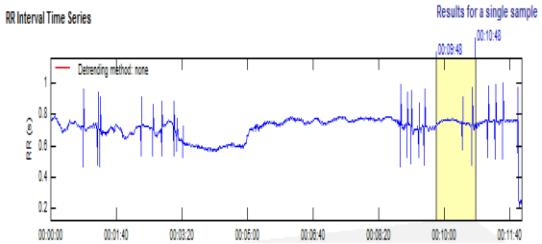

Figure 3 separating a one-minute of RR interval distances to the start time of the VT attack on the HRV signal

4-2 Selection of sample RR intervals from HRV signals in the MR group:

In this group, samples of one minute of RR intervals were selected on each HRV signal. Since no attack has been made, it is possible to select these intervals in each signal segment, which in this project, these intervals were selected at the beginning of each signal.

5 Feature extraction

Regarding the effective role of detecting HRV signal changes in predicting the VT, the values of linear and nonlinear features are extracted from the selected one-minute intervals of the HRV signals in the MR and Pre-vt groups. These features include, time-linear features (Mean RR, STDNN, Mean HR, STD HR, RMSSD, NN50, pNN50, TINN),frequency-linear features(LF ،HF ،VLF ،LF/HF) and nonlinear features (REC، DET، shanEn, RPA، Lmean، Lmax،، DFA,α1, α2, SD2, SD1، ApEn، sampEn، D2)(5).

The normalization is done on each feature during the corresponding class For each feature, each feature is divided by the maximum value of that attribute throughout the corresponding class, in this case, the range of data is between [-1, 1]. In order to study the values of the properties and how changes in their values over different time periods, three different modes were studied.

First Mode: Short Term study

In this case, after the extraction of the features presented from the intervals close to the attack (70 to 10 seconds before) in the patient group and the intervals of mr, t-test was used .The characteristics that had the most ability to differentiate between the two healthy and healthy groups were selected. These features included Mean RR, Mean HRV, STD HRV, NN50, TINN, SD2, sampEn, 2α, Lmax, Lmean, DIV, shanEn . Then a data matrix with dimensions of 212 × 12 was constructed. In this matrix, the number of rows is equal to the number of data and the number of columns is equal to the number of attributes, and the class data label is also added as a column to the matrix, and finally the matrix 212 × 13 was created.

Second Mod: long Term study

After extraction of features from distant intervals (130 to 70 seconds before) in patient group and intervals of mr, using t-test analysis and appropriate features were selected. then the data matrix with dimensions of 212 × 8 was created.

Third Mode: Difference Study

In this case, both short-term and long-term periods were considered. After extracting features from both intervals, the difference between the values of the features between these two intervals was calculated. After using the t-test, the frequency characteristics were only eliminated, and other features remained in the feature matrix. In order to reduce the dimensions, the PCA method was used and finally the characteristic matrix with 212 × 11 dimensions was created. .

6 Artificial Neural Network Design:

In all three cases, for the separation of the two healthy and patient groups of the Multilayer Perceptron Neural Network (MLP).Also, the network error was calculated based on the network output difference with the actual label of the available data in the Physionet site.Then, two-thirds of the data was used for training, and one-third for testing the network. And evaluation of the results is based on the output of the test data. Given the presence of two VT patient class data, a neuron is placed in the output layer, which has two modes 0 and 1. The class label 1 was considered for the patient group VT and the class label 0 for the healthy group. The parameters for the proposed neural networks are presented in Table 1

7 Results

Sensitivity, degree of specificity and accuracy are reported in Table 4. By comparing the results obtained from the network performance in each of the three stages, The best performance of the network in prediction of VT attacks was in the third phase, which examined the changes in features between the two short and long intervals before the attack, This indicates significant changes in the values of the features over a period of 130 to 10 seconds before the start of the attack. Eventually, this interval was set at 94.28% for the prediction. In none of the predictive processes, frequency features were not successful in the statistical test, which indicates that the emotionsand emotions and excitement of

theindividual were not affected before the attack occurred.

Table1 Artificial Neural Network Specifications

parameters	Description
Neural network structure	Multilayer Perceptron(MLP)
Neural Network Type	Feed Forward
Error function	MSE
Learning algorithm	Backpropagation
Number of hidden layers	2
The number of hidden layer ‘neurons	20 and 5
Allowed error at the training stage	0.0001
Learning rate	0.01
The actuation function of the middle layer	Tangent hyperbolic
The actuation function output layer	Softmax

Table 2 Evaluation results

	Sensitivity	Specificity	Accuracy
First mode	74.28%	62.85%	68.57%
Second mode	80%	54.28%	67.14%
Third mode	91.42%	97.12%	94.28%

8 Conclusion

The algorithm used to obtain the correct accuracy and timing for prediction at three intervals before the start of the attack was considered, It is very important to obtain proper accuracy in terms of treatment. If the VT attack is incorrectly predicted. The person is shocked and can cause death. Also, if there is no prediction of the attack, there are no therapeutic proceedings and there is still a possibility of death. By comparing the results obtained in all three intervals, the two-minute prediction horizon, with a Accuracy of 94.28%, was selected for prediction. And according to the method of treating VT, in this period of time necessary for the preparation and emergency treatment is provided.

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