Designing an Alarm System for the Stratification of Risk of Cardiac Arrhythmias

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Abstract

The idea of this research is to propose an alarm system that can alert the early establishment of an event paroxysmal ventricular tarquicardia (PVT), from study of heart rate variability (HRV). The study of the variability is support in the frequency of abnormal patterns prior to the events. We select and analyze in detail 24 hours records from dynamic electrocardiography (Holter). We selected 88 one-hour segments prior to the events of PVT, and once analyzed the system found an efficiency of 77% in early detection of the establishment of the arrhythmia, with an average prediction time of 43±8 minutes distant from events, statistically significant result. To assess the percentage of false alarms we evaluate 103 hours from control healthy subjects, resulting in a specificity of 85%.

1. Introduction

The Paroxysmal Ventricular Tachycardia (PVT) is a ventricular rhythm among 120 and 220 beats per minute, and it appears with abrupt beginning and end. Although PVT can to produce few symptoms, even at frequencies up to 200 beats per minute, it´s extremely dangerous. It usually occur with other heart diseases that cause serious injury to the ventricules. It might require emergency treatment because the ventricles are unable to fill properly, tending to decline the blood pressure and leading to a heart failure. Likewise, there is a risk of PVT aggravation and it transforms into ventricular fibrillation [1–4]. This picture makes evident the need to address the search for strategies for preventive treatment in order to improve quality of life of affected people.

In previous research [4–7] studying the HRV has become the tool for finding predictors associated with such anomalies in the heartbeat, because it´s obtained from a non-invasive and low-cost technique. It´s a well-known standard by specialists physicians. The traditional study includes analysis in time domain, in frequency domain and using of non-linear modeling techniques. The results have been partial in some cases and successful in others, but few [8–10] compare results with control groups to evaluate the efficiency of the method.

In this paper, it is proposed an alarm system in order to establish different levels of alert associated with the establishment of risk of PVT. It was selected and studied in detail 24 hours records from dynamic electrocardiography (Holter). 88 one-hour segments prior to events of PVT and 103 hours from control healthy subjects. The indicator of risk to the alarm system part of the study HRV in the number of snapshots pulsations obtained from the RR intervals prior to the arrhythmia episode (fig.1) and basically consists in identifying characteristic patterns associated to anomaly and determine how often they occur.

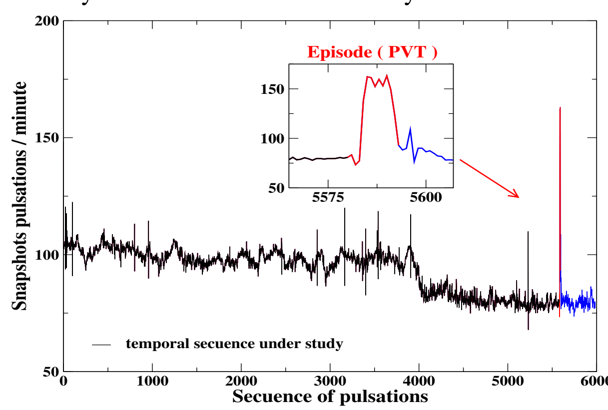

Figure 1. Temporary sequence of snapshots pulsations per minute, prior to a PVT´s event

2. Holter ECG recordings

The logs 24-hour ECG were provided by the Institute of Tropical Medicine, UCV and were obtained with a magnetic recorder of 3 channels (Rozinn Electronics, Holter Recorder Model 151). The digitization was made by a Silicon Graphics Workstation to 500 samples per second with a resolution A/D of 8 bits. The one-hour records prior to the episodes were identified by medical specialists and subsequently removed for analysis of the HRV with the software that we developed for this study [11–14].

3. Subject data

Eighty-eight PVT episodes obtained from continues 24-h electrocardiographic (ECG) recording from 55 asymptomatic patients without a history of recurrent VT (33 men and 22 women, mean age 59±15 years [range 25 to 86 years]) were analysed in this study, besides 103 one hour records from 27 control subjects (15 men and 12 women, mean age 36±8 years [range 20 to 51]) who didn´t have neither clinical symptoms nor suggestive of heart disease when following test was practiced: Clinical evaluation, Test Machado-Gerreiro (immunological test that detects the presence of antibody of the T. cruzi), thorax´s X-ray, Echocardiogram, Electrocardiogram of average signal, Test of effort, Protocol of Bruce, Standard electrocardiogram of 12 derivations, 24 hours dynamic electrocardiography (Holter). The PTV episodes were obtained during a routine Holter analysis and thirteen had more one episode. Records with PVT events were selected according to the following criteria: a low noise level, distanced a period longer than one hour from previous events and belonging to subjects who are not medicated.

4. HRV analysis

The HRV analysis is supported in studying occurrence of abnormal patterns preceding events PVT. The analytical methodology used is as follows: we proceed to divide the hour preceding PVT in a temporal sequence of windows (fig. 2). Within each window there is a temporal sequence of values that correspond to snapshots pulsations that can be viewed as a sequence of vectors to a given dimension d. It is associated with each d-dimension vector its euclidea distance to a group of vectors, with the same size who are chosen at random within the control registers. It´s counted the number of vectors that are outside the court a percentile level previously set for the distribution of vectors of euclidean distances in the control group. These vectors are identified as atypical vectors . Once identified the number of atypical vectors within each window to a dimension d, and for a given percentile, we study the occurrence of these vectors atypical in a series of groups called window´s block. It's built as a grouping of windows arranged in three consecutive groups (fig.3), where each group can contain a single window, a pair of windows (double), three windows (triplets), etc. The block moves by the registration in steps of a window and parameters such as the number of windows per group with a number prefixed of atypical vector by window, allowing detect the presence of patterns, are evaluated. It is considered an active block, whether in each group is satisfied that it contains the number of windows with the requisite number of atypical vectors required at least.

5. Alarm system

The presence of active blocks promotes the firing of the alarm system, the activation levels are so progressive as they detect presence of a pair of consecutive active blocks (pattern), see fig.3. Thus, the initial occurrence of a pattern, trigger the first alarm level, with the presence of a second pattern, this alert level will rise, and so on until achieving the third level, which represents the maximum alert. It only requires the presence of three patterns to achieve the level of maximum alert. The future presence of patterns reinforce this condition.

6. Results

Method´s efficiency was evaluated measuring the percentage of cases in which the alarm system was activated at its highest alert level, as well as the percentage of false alarms from the control group, varying the size of the block, number window and the minimum number of atypical vectors by window. Such an evaluation can be seen in fig.4. From this chart it appears that maximum efficiency in the detection of preventive PVT cases with the fewest false alarms from healthy records, is achieved by evaluating the occurrence of patterns with a block of length 9, one window (1 minute) per group containing at least the presence of a atypical vector with dimension 5, and a percentile of 99%. For one-hour records preceding the events of PVT we found an average prediction of 43± 8 minutes (fig.5), which is a significant time within this range. It is also important to comment on the high frequency of activity (or permanently activity) in a level of maximum alert system (fig.6), by 49% cases which submitted the event of PVT, as well as the low frequency for activation control group, except one particular case.

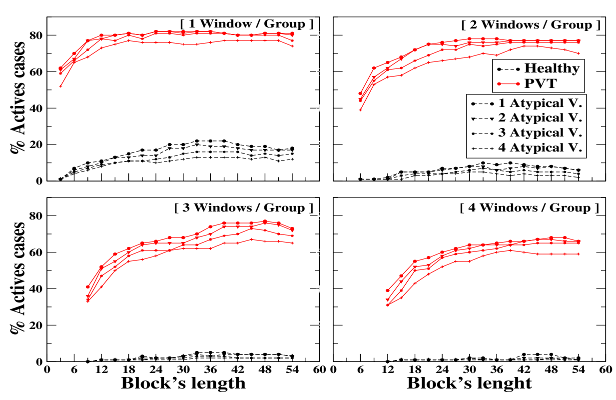

Figure 4. Percentage (%) of active cases at Level 3 of the alarm, varying parameters such as minimum number of atypical vectors by window and the number of windows per group within each block.

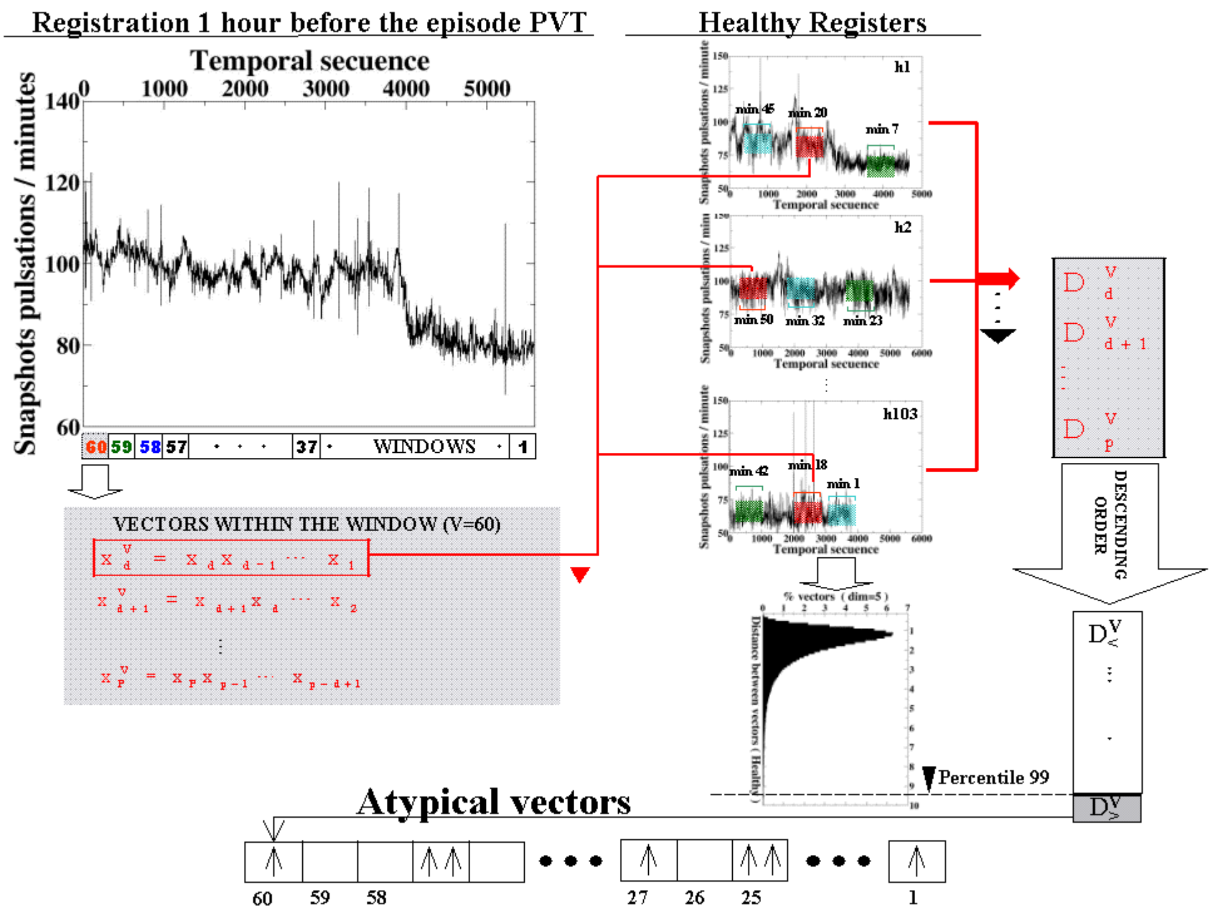

Figure 2. Detection of atypical vectors.

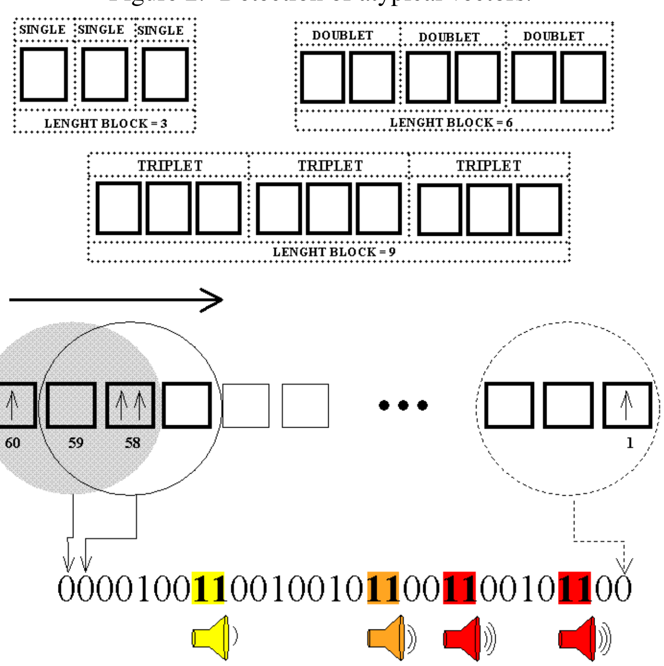

Figure 3. Detection of dynamic patterns.

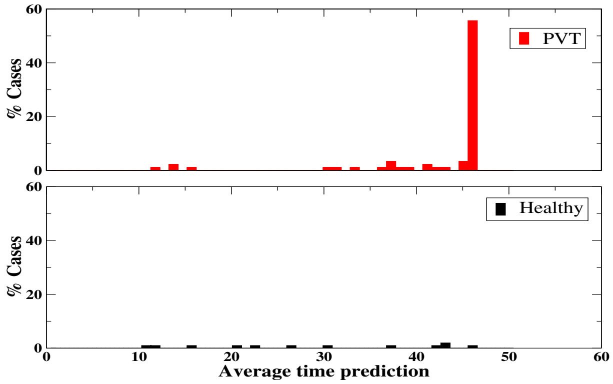

Figure 5. Distribution % of active cases on high alert, as a function of time to distant PVT´s event (fig. top), and false activations in healthy´s registers (fig bottom).

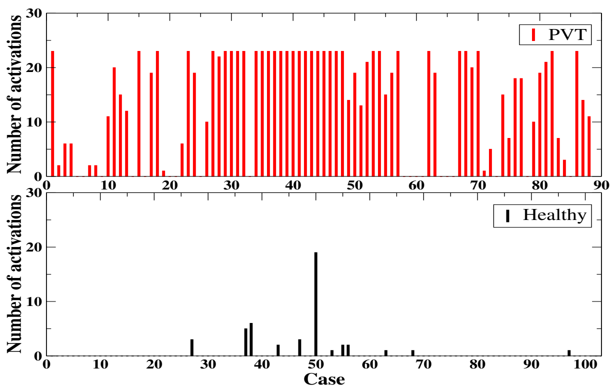

Figure 6. Number of activations on high alert in records with PVT (fig. top.) and healthy´s records (fig. bottom).

7. Conclusion

This study allowed to detect the temporal evolution of patterns associated with the development of the crisis, through the analysis of behavior presented by the indicator studied. A discriminant criteria for the activation of alarm is stablished and we obtain a sensitivity of 77% and specificity of 85%. This result suggests a possible strategy for detecting and preventing this kind of abnormality in heart rhythm.

[No windows/group = 1] [No atypical vect = 1] [length block = 9]				
Activity Level	PVT	time	Healthy	time
0	19%		85%	
1	1%	48±4	2%	39±10
2	3%	45±7	3%	32±14
3	77%	43±8	10%	26±16

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