Early detection of ventricular tachycardia with sending messages to cell phone

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Abstract. Sustained ventricular tachycardia (VTs) can be asymptomatic for some people, but for others is deadly because it is a major cause of sudden cardiac death [1]. Some patients may present this arrhythmia, and even so, they decide to drive a car increasing the likelihood of VTs, putting at risk not only his life but that of the other drivers. We developed a system for early detection of VTs, consisting of EKG sensors, a card of processing and a cell phone, which detects this arrhythmia, gives an alarm signal to the driver, and it simultaneously sends text messages to a specialist doctor and a relative or friend, all in real time. This design was conditioned to the car, is light and comfortable, that allowed that work of car's driver without discomfort. This system will save lives, since in case of emergency sends a help message, no matter where you are in the driver.

1. Introduction
According to statistics conducted by the American Heart Association (AHA) [2] in the world 27.7% of deaths are caused by heart disease, particularly in Colombia is estimated that deaths from this cause are 30% where 8% of these are due to sudden death caused by cardiac abnormalities. Moreover, the elderly are more prone to arrhythmias such as ventricular tachycardia, especially when they are doing activities that generate high stress such as driving, due to heavy traffic and the recklessness of other drivers. Whereas this situation has caused in the past three years more than 10% of car accidents, one in Bogota and 4% of these accidents, accidents causing large-scale [3].

From a clinical standpoint tachycardia may have a ventricular or supraventricular origin and the differentiation is extremely significant, since this depends on the treatment to try to reverse the arrhythmia in the acute phase, the long-term management and prognosis of the patient same [4-6]. Consequently the causes involved in sudden cardiac death are diverse. In that case have been implicated supraventricular tachyarrhythmias, bradyarrhythmias, hemodynamic ischemia and obstruction, but are the predominant cause of malignant ventricular arrhythmias [7-12], that is why in patients considered high risk are monitored constantly. Regarding to development of devices for automatic analysis of cardiac abnormalities has increased in recent years. Currently, the devices automatic of detection ADD are equipment of microprocessor-based devices, highly complex, and then break that record the EKG signal to determine whether it is compatible with ventricular fibrillation (VF) or ventricular tachycardia (VT) without pulse [13].

In fact, with this framework is need to developing an electronic device that can capture the subject's electrocardiogram signals, processed to detect when it happens arrhythmic heart rate and once classified as ventricular tachycardia, resulting in an alarm issue the subject and simultaneously send
alert messages to two, the medical specialist and a family. This is how the development of this innovative device is beneficial for all those who suffer cardiac arrhythmias such as ventricular tachycardia is because it gives confidence to enable them to perform their daily activities, such as driving a car, unaccompanied by any person. When an accident happened, this device facilitated the research process, because it carries a record of cardiac abnormalities through text messages sent.

2. Materials and Methods
First, based on current requirement, initially prepares a list of design requirements to make of device functional.

2.1. Materials
Adaptive power supply to a car, portable, lightweight, detecting 140 bpm, alarm only sent by the user is authorized, using a massive communication system to send to alarm.

Then, the tests are performed with ten subjects elderly that have been, although only once, diagnosed with arrhythmia, and they still are drivers of cars. The type of EKG recording is noninvasive, consisting of three surface electrodes located in the chest, these subjects recorded P-R interval between 0.19s to 0.12s, and between 70 to 80 bpm in steady state. In fact, the pre-processing of data, starts with an analysis of uncorrelated noise, thus implementing a band pass filter $f_s=5\text{Hz}$, $f_i=0.33\text{Hz}$ and $f_c=2.665\text{Hz}$, in addition of elevator level of twice the original signal amplitude. Therefore, the data processing is done with PIC 16F877A Microcontroller with USART communication port and Bluetooth transmission to module Parani ESD 200 that meets 802.15 protocols. Then, into cellular phone 3G programming, we implement to API jsr 82 for receiving, and API jsr 120 for sending messages.

2.2. Method
This work has developed in stages, as shown in Figure 1. The first stage involves the acquisition of the subject's electrocardiogram recording, electrode placement, signal transmission to the electronic card; the second stage, performed the pre-processing of signal: filtering, amplification and dc level change; the third stage, the signal processing performed: sampling, detection of heart rate and thresholding of information; the fourth stage, is performed by Bluetooth communication protocol 802.15 to a cell phone ; the fifth stage, takes place programming to receive and store information in cell phone and send alarm messages to selected phone numbers, and in the sixth stage is verified that the information of the date and time of delivery was transmitted and stored.

![Figure 1: Development stages of the detection system and send alarm](image)
2.2.1. Acquisition of EKG

The acquisition circuit design employs three leads I, II and III, and a gain resistor \( RG \) regulating the gain of the system by equation (1):

\[
G = 1 + \frac{50\Omega}{R_G}
\]  (1)

2.2.2. Pre-processing data

In the EKG signal preprocessing were implemented several techniques to refine the signal to analyze.

- **filtering**
  As a result of noise due to the high frequencies and interference from the mains, 60Hz, we design a band-pass filter which limits the frequency spectrum of the EKG between 0.5 Hz and 150 Hz. In addition, we implemented a notch filter that removes narrowband interference from 60Hz. This conditioning also helps to avoid the phenomenon of overlap in the intervals of scanning. Finally, another low-pass filter that eliminates the noise from the signal conditioning.

- **Voltage level-shifting**
  The output from the preamp brings EKG signal referring to the common floating in order to make the link between references to ground, it is essential to raise the reference voltage signal. Given that, the EKG signal has variations in the range of + / - 1V, we developed a voltage level-shifting of 2V for that change this reference make to EKG signal can be vary within positive values.

- **Processing data**
  Now, for QRS detection using the A / D converter implemented in the 16F873A microcontroller with 4 MHz crystal. Thus, each instruction takes the time to 4 periods, i.e.:

\[
F_{\text{crystal}} = 4 \text{ MHz}
\]

\[
T_{\text{crystal}} = \frac{1}{4\text{MHz}} = 0.25 \mu\text{s}.
\]

\[
T_{\text{instruction}} = 4 \times 0.25 \mu\text{s} = 1\mu\text{s}.
\]  (2)

Given that ventricular tachycardia cardiac pulsation is fast, this is characterized by 3 or more consecutive premature ventricular beats. Thus, the analysis is to take the time it takes the development of 3, 5, 10 and 20 QRS complexes so we can determine the heart rate of each subject, as shown in Table I.

| Table 1 Registration time at different bpm |
|-------------------------------------------|
| Time (s) | 10 bpm | 3 bpm | 5 bpm | 20 bpm |
|----------|---------|-------|------|--------|
| 1        | 600     | 180   | 300  | 1200   |
| 2        | 300     | 90    | 150  | 600    |
| 3        | 200     | 60    | 100  | 400    |
| 4        | 150     | 45    | 75   | 300    |
| 5        | 120     | 36    | 60   | 240    |
| 6        | 100     | 30    | 50   | 200    |
| 7        | 85,714  | 25,714| 42,857| 171,428|
| 8        | 75      | 22,5  | 37,5 | 150    |
| 9        | 66,667  | 20    | 33,333| 133,333|
| 10       | 60      | 18    | 30   | 120    |
| 15       | 40      | 12    | 20   | 80     |
| 20       | 30      | 9     | 15   | 60     |
| 25       | 24      | 7,2   | 12   | 48     |
| 30       | 20      | 6     | 10   | 40     |
| 60       | 10      | 3     | 5    | 20     |
Now, in Figure 2 shows the barrier of 140 bpm, located exactly in the 4.28s. This means that the time of 10 QRS complexes takes less than 4.28s. This meaning the possibility that the subject is suffering VT. Therefore, with this data we made the decision about how many pulses take to detect VT and also to determine the total time of detection, by the equation:

$$t_{10} = \frac{60 \text{ bpm} \times 10 \text{ p}}{140 \text{ bpm}} = 4.28 \text{ s} \quad (3)$$

Figure 2: Registration of duration to different beats

- Communication 802.15
  Subsequently, to establishing the connection between the electronic card processing and cell phone we was used Parani ESD module because it allows the port USART interface between the microcontroller and Bluetooth protocol 802.15. This connection has the following characteristics: baud rate 9600bps, no flow control, no parity and no authentication. In addition, to establish Bluetooth connections from mobile devices, we program in J2ME Java language, using the settings for devices with limited connection (CLDC) that maintains, if possible, the characteristics of Java on devices limited to 16 processors or 32-bit, aged 8 to 32 MHz and a total amount of memory available for Java platform at least 160-193 Kb.

- Programming
  The Application Programming Interface API, used in programming the cellular telephone was JSR-82, which is divided into two parts: javax.bluetooth and javax.obex. Both packages are fully independent. The first defines basic classes and interfaces for device discovery, service discovery, connection and communication. The second protocol can handle high-level OBEX (Object Exchange) used mainly for file sharing, where cell phones are seen as the client in the connection.

- Information register
  At last, in this stage was developed in the language J2ME, with API JSR-120 for exchanging messages over wireless networks. Thus, from this API you program the SMS short message content and determine which users will alarm. Furthermore, keep a record of the date and time the messages were sent and which received a recorded number of received responses.

3. Results
The results show that the developed system is functional and can be installed in any car because it meets the requirements requested, that is to say, adaptive power supply to a car, portable, lightweight, detecting 140 bpm, alarm only sent by the user is authorized, using a massive communication system to send to alarm.
Tests confirmed to us the different values given to the programming of devices for early detection of VT. Thus, with regard to threshold, the Figure 3 shows one of the tests undertaken to confirm the optimal cut-off level programmed into the microcontroller include allowing a greater degree of reliability when QRS complex detection. Nevertheless this threshold can be changed for each subject according to their corporal composition and strength of its beats, even so, for subjects studied at early-detection system of VT operated optimally.

![Figure 3: Cut-off level for the detection of the QRS complex](image)

Furthermore, we tested for reliability in the early detection of VT now on the minimum number of beats necessary to establish a limit. Table II shows the results when comparing EKG simulator with a real subject. As a result of testing the system works correctly in the early detection from 140 bpm.

| User       | Signal | bpm | Alarm | Sent to SMS |
|------------|--------|-----|-------|-------------|
| Simulator  | EKG    | 40  | NO    | NO          |
| Simulator  | EKG    | 60  | NO    | NO          |
| Simulator  | EKG    | 80  | NO    | NO          |
| Simulator  | EKG    | 100 | NO    | NO          |
| Simulator  | EKG    | 120 | NO    | NO          |
| Simulator  | EKG    | 140 | SI    | SI          |
| Simulator  | EKG    | 180 | SI    | SI          |
| Subject    | Normal | 70  | NO    | NO          |
| Subject    | agitated | 140 | SI    | SI          |

Regarding the time spent by the system to determine whether the subject has VT. The system analyzes ten beats in a row, then measures the time of these ten pulses and thus the present data analysis for 95% certainty of presence VT. Table III shows that the detection is more delayed when the subjects undergoes abrupt changes your heart rate because the system takes more time analyzing...
this sudden change in the signal. Otherwise, when the subject has a heart rate progressively increases
the system detects the anomaly and immediately sends the alarm.

### Table 3 TIME OF DETECTION Simulator VS Subject

| User       | Initial heart rate (bpm) | Final heart rate (bpm) | Alarm | Time of detection (s) |
|------------|--------------------------|------------------------|-------|-----------------------|
| Simulator EKG | 60                       | 60                     | NO    | -                     |
| Simulator EKG | 60                       | 100                    | NO    | -                     |
| Simulator EKG | 60                       | 140                    | SI    | 4.5                   |
| Simulator EKG | 80                       | 140                    | SI    | 4                     |
| Simulator EKG | 100                      | 140                    | SI    | 3                     |
| Simulator EKG | 120                      | 140                    | SI    | 1                     |
| Simulator EKG | 60                       | 180                    | SI    | 4.5                   |
| Subject     | 120                      | 140                    | SI    | 1                     |
| Subject     | 140                      | 140                    | SI    | 1                     |

Finally, with respect to the generation of emergency message could not be established that is the
exact time of the generation of the message, because this process takes place in milliseconds and we
did not have a method that allows us to synchronize the device with cell phone to compare these times.
However, in terms of time taken to send the message, was measured with a stopwatch from the time
the alarm is activated when you listen to or view a new alarm message in the cell phone of the person
will help to subject. As shown in Table IV.

### Table 4 TIME spent in sending a message

| Number of messages | Mobile operator output | Mobile operator destination | Time (s) spent in sending | Average (s) time spent in sending |
|--------------------|------------------------|----------------------------|---------------------------|----------------------------------|
| 1                  | Operator 1             | Operator 1                 | 9.2                       | 9.2                              |
| 2                  | Operator 1             | Operator 1                 | 9                         | 9.1                              |
| 3                  | Operator 1             | Operator 1                 | 10.3                      | 9.9                              |
| 4                  | Operator 1             | Operator 1                 | 9.1                       | 9.4                              |
| 5                  | Operator 1             | Operator 1                 | 8.6                       | 9.24                             |
| 6                  | Operator 2             | Operator 1                 | 15.8                      | 10.3                             |
| 7                  | Operator 2             | Operator 1                 | 20.5                      | 11.8                             |
| 8                  | Operator 1             | Operator 2                 | 19.3                      | 12.7                             |
| 9                  | Operator 1             | Operator 2                 | 14.6                      | 12.9                             |
| 10                 | Operator 2             | Operator 2                 | 8.4                       | 12.5                             |

When messages are sent between the same operators generated text messages arrive in an average
of 9s to their destination, whereas when the messages generated are sent to different operators take an
average of 18s to arrive successfully at the person who will help test’s subject.

### 4. Discussion

Once the system tests for early detection of VT can confirm that when a heart rate above 140 pulses /
min \[^{[14-16]}\] without having made any physical effort the patient is at risk of suffering ventricular
tachycardia, which was the appropriate criterion for selecting the threshold of detection to provide
early warning.
In spite of the early system functions optimally, still the problem of knowing where it is geographically the subject who reported the alarm. Indeed, a solution can be reported by Dr. Haroon Rashid [17] which suggests the use of modulo Global Positioning System (GPS) some 3G equipment, so that when generating the emergency message that contains the user's exact locations.

With respect to the power supply, we have had some minor problems with the energy that is taken from the car, this due to the noise factor. We suggest that to avoid these inconveniences, it is necessary to use a portable power supply (external battery) the system of early detection of VT.

Analyzing Table 1 we could determine that when taking a smaller number of beats for the detection of VT, this detection will take less time. Nonetheless, it increases the number of false positives the system, causing a glut in the output of alarm messages. For this reason, we suggest detect VT with 10 pulses as the time despite being a bit more for the less pulses the error is much smaller.

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