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Design a Monitoring Device for Heart-Attack Early Detection Based on Respiration Rate and Body Temperature Parameters

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Abstract

Acute myocardial infarction, commonly referred to as a heart attack, is the most common cause of sudden death where a monitoring tool is needed that is equipped with a system that can notify doctors to take immediate action. The purpose of this study was to design a heart attack detection device through indicators of vital human signs. The contribution of this research is that the system works in real-time, has more parameters, uses wireless, and is equipped with a system to detect indications of a heart attack. In order for wireless monitoring to be carried out in real-time and supported by a detection system, this design uses a radio frequency module as data transmission and uses a warning system that is used for detection. Respiration rate was measured using the piezoelectric sensor, and body temperature was measured using the DS18B20 temperature sensor. Processing of sensor data is done with ESP32, which is displayed wirelessly by the HC-12 module on the PC. If an indication of a heart attack is detected in the parameter value, the tool will activate a notification on the PC. In every indication of a heart attack, it was found that this design can provide notification properly. The results showed that the largest respiratory error value was 4%, and the largest body temperature error value was 0.55%. The results of this study can be implemented in patients who have been diagnosed with heart attack disease so that it can facilitate monitoring the patient's condition.

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I. INTRODUCTION

Acute Myocardial Infarction, commonly referred to as a heart attack, is the most common cause of sudden death in urban and rural areas [1]. According to the World Health Organization, cardiovascular disease is the number one cause of death globally. In 2017, it was estimated that 17.8 million deaths worldwide were caused by cardiovascular disorders. The heart itself gets oxygen and nutrients through blood vessels called coronary arteries. When blood flow to the heart is cut off suddenly, there will be a decrease in the supply of oxygen and nutrients so that which can cause permanent damage to vital organs. This is the heart attack definition [2]. Changes in the indications of vital organs in patients with attacks will provide basic conditions for patients with heart disease to experience repeated attacks. Therefore it is necessary to have a system that can monitor the patient's condition [3]. Monitoring is very necessary if there are symptoms of a disease that must be taken quickly so that the patient's condition does not worsen. The patient's condition can deteriorate anywhere and at any time. For this reason, we need a device equipped with a system that can notify doctors so that they can take action if the patient shows results that are less or more than normal [4]. There is substantial evidence that changes in respiratory rate can be used to predict potentially serious clinical conditions such as cardiac arrest [5]. According to the American Heart Association (Dallas, TX, USA) and the Mayo Clinic (Rochester, MN, USA), one of the

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most commonly recognized symptoms of a heart attack is an indicator of abnormal body temperature [6]. Body temperature is the difference between the amount of heat produced by body processes and the amount of heat lost to the external environment [7]. The changing nature of heat greatly affects the clinical problems that each person experiences. Some parameters that are quite often found are heart attack patients experiencing tachycardia and not infrequently accompanied by tachypnea [8]. Based on the research of A. Putot, the onset of symptoms of a heart attack along with acute infection is characterized by symptoms of tachycardia (>100 beats/min), tachypnea (>24 breaths/min), and symptoms of fever (>39°C) [9]. According to research by T. Ilczak, the parameters considered significant as predictors of a heart attack include respiratory rate less than 12/minute and heart rate less than 60/minute [10].

Based on a literature search, in 2018, a study was made on Monitoring Heart Rate, Body Temperature, and Respiration Based on Telemedicine Via Android by Anggit Ananda Solichin. In this study, we were able to take measurements of body temperature, heart rate, and respiration that were displayed wirelessly via android, but in this study, there was no abnormal notification for early detection of heart attacks [11]. In the same year, Rizal Agung Prayugo et al. conducted research on monitoring bpm, body temperature, and respiration on computer display via Bluetooth and data delivery via SMS. The disadvantages of this study are that the temperature sensor response is long enough to detect, and the sensor is still less accurate on the respiratory rate [12]. In 2019, Priyanka Sasidharan, et al. have designed a Wearable Cardiorespiratory Monitoring Device for Heart Attack Prediction. Where the device is designed to be wearable to monitor vital signs and detect abnormalities, including heart rate, body temperature, SPO2, and respiration rate for patients who have a history of a heart attack. The results of the monitoring data can be evaluated through a mobile application, but the design has a drawback that it is not equipped with ECG parameters [13]. In 2018 the Measurement of Respiratory Rate Using Piezoelectric sensors was made by Shankar N et al. This study is used to monitor the respiratory rate per minute using a piezoelectric sensor to detect breathing placed on the patient's chest. The application of the display uses a PC using a USB serial RS232 on the respiratory value delivery system. This research shows that the use of a piezoelectric sensor can be used to monitor respiratory rate. However, this study uses a USB controller, so there is still a cable between the tool and the PC [14]. Furthermore, Gede Aditya Mahendra Oka made a Design of Vital Sign Monitor with ECG, BPM, and Respiration Rate Parameters that can monitor vital signs in real-time but cannot be monitored remotely and has not been equipped with a system that can detect a heart attack [15]. In 2017 the safety belt integrated sensor system for heart activity and respiration was made by Leicht et al. This study uses a piezoelectric sensor to monitor respiration and uses an optical sensor to monitor heart rate [16]. Then in 2017 Abhishek Singh, et al. made a real-time respiration rate measurement using a temperature sensor. This research is designed to detect respiratory frequency using a temperature sensor. However, it is not accompanied by the detected respiratory rate values , so that the accuracy of the sensors used cannot be known [17]. In the "Design and Implementation of a Wireless Patient Health Monitoring System" study by Manzombi et al., regarding monitoring the heart rate of patients in hospitals using a 433MHz transmitter and receiver radio frequency communication system has the advantage of being able to transmit in real-time, but in this study only can monitor the patient's heart rate [18]. Next is the implementation of a wireless sensor network for medical applications, which has been carried out by Hayder J Hassaballah and Rashid A Fayadh on a method of monitoring heart rate and SPO2 using HC-12 with the aim of being able to easily transmit with a distance of tens of meters in a monitoring system in hospital but this method is still used only for monitoring SPO2 values and heart rate [19]. There are various types of delivery modules that can be used to replace cables as the delivery of each parameter to monitor patients, one of which is the HC-12 RF module delivery module where this module can be used as a transmission module between remote devices with low power consumption [20][21].

Based on the weaknesses and limitations that have been mentioned in previous researchers among others, 1) Incomplete parameters, 2) Still using cable in data transmission, 3) Monitoring can not be in real-time and continue, and 4) Not equipped with a notification when a heart attack occurs. Therefore, in this study, a Design of Monitoring Device for Early Detection of Heart Attack with Respiration Rate and Body Temperature Parameters was made with the aim of facilitating the monitoring process for patients so as to prevent the risk of sudden death caused by a sudden heart attack. This design can display the value of vital conditions (Respiratory Rate and body temperature parameter) in real-time using a wireless transmission system or without using wired media as data transmission using the wireless module and displayed on a PC. This design is also equipped with notifications so that patients can be treated immediately.

This Article is composed of: Chapter 1 introduction, Chapter 2 Material and Methods, Chapter 3 Result, Chapter 4 Discussion, Chapter 5 Conclusion, and Chapter 6 Reference.

II. MATERIALS AND METHODS

A. Experimental Setup

This study was conducted using a piezoelectric sensor mounted on the respondent's abdomen and a temperature sensor to monitor the body temperature attached to the respondent's axilla. The subjects were randomly sampled and the data collection is repeated for 5 times.

1) Materials and Tool

This study uses a ceramic piezoelectric sensor (Polyvinylidene Fluoride, OEM, LA2019051700ljl, China) to detect respiration placed on the abdomen and a DS18B20 temperature sensor (Dallas temperature sensor, US) to monitor body temperature. Components used such as a summing amplifier circuit to amplify the respiration signal, a low pass filter circuit to remove noise. The resulting data from processing

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the ESP-WROOM-32 module (211-161007, Espressif Systems module, Shanghai China) and Arduino software (Version 1.8.14) are sent using wireless module (HC-12, China) to the PC.

2) Experiment

In this study, after the module was finished, a test was carried out using a patient monitor (BSM-2301K, Nihon Kohden, Japan) to compare the value of the respiratory results on the respondent, and a test was carried out using a thermometer to compare the body temperature result value to the respondent.

B. The Diagram Block

In **Fig. 1**, on the patient's abdomen, a belt will be attached in which there is a piezoelectric sensor (to detect changes in values when there is movement in the abdomen). The respiration signal was then amplified using a summing amplifier and filtered using a lowpass filter. Then, in the axillary part of the patient, a temperature sensor will be installed to detect the patient's body temperature value. All outputs of each sensor will be entered into the microcontroller that has been programmed to be processed, then sent by the transmitter using a wireless module. The data sent will be received by the receiver block using the wireless module, and the received data will be processed and displayed on a PC using the Delphi application by calling the data according to the COM value/data input. And when an abnormality is detected in the parameter value (indication of a heart attack), the doctor will automatically get a notification in the form of a heart attack warning. Indications of the heart attack in question are, when:

a. Heart Rate > 100 BPM and RR > 24 BPM
b. SPO2 < 93%
c. Heart rate > 100, RR >24 BPM, body temperature >39 ºC
d. Heart Rate < 60 BPM, RR < 12 BPM

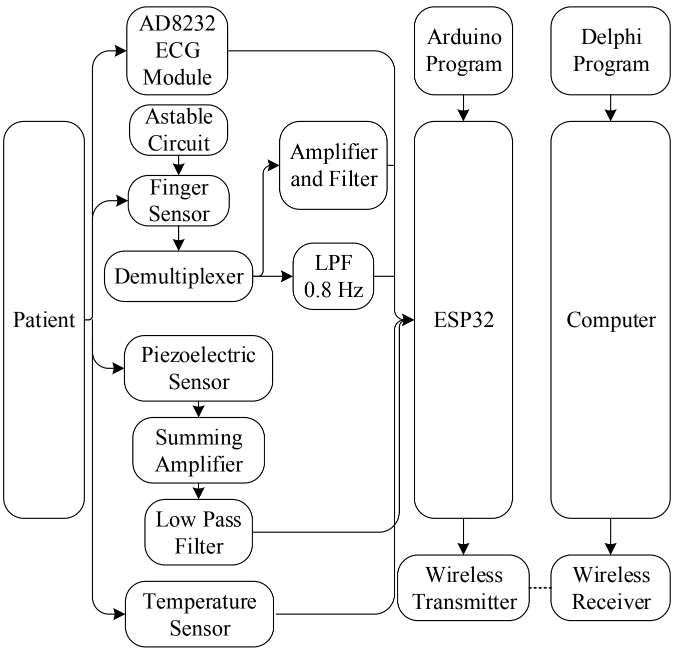

Fig. 1. The Diagram Block of the Monitoring Device

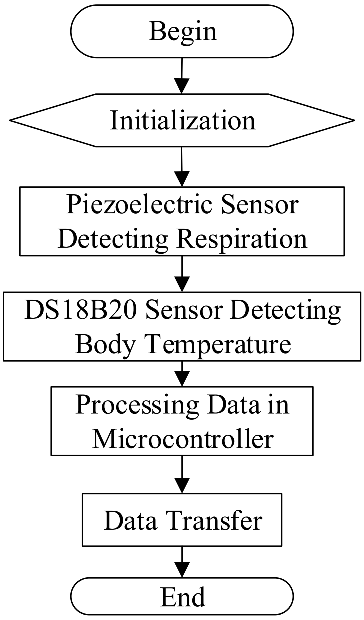

Fig. 2. The Flowchart of the Arduino Program

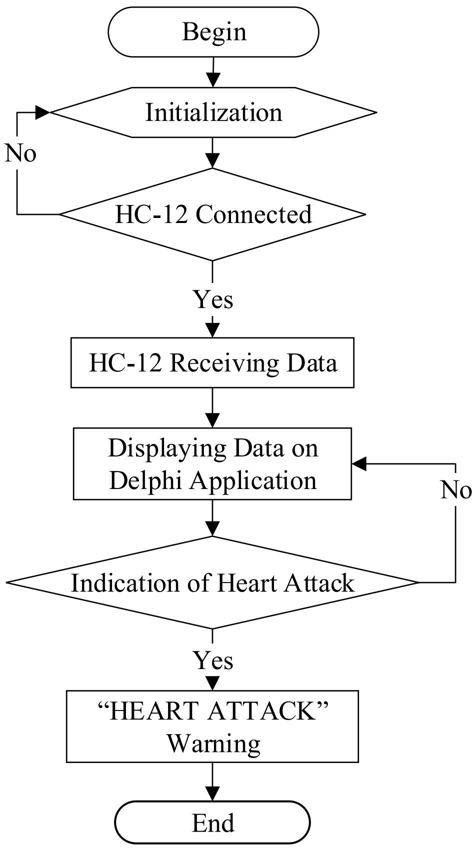

Fig. 3. The Flowchart of the Delphi Program

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C. The Flowchart

As shown in **Fig. 2**, when the device is turned on, it will initialize, then the piezoelectric sensor will detect the respiration value, and the DS18B20 sensor will detect the body temperature value, which will be processed on the microcontroller. The processed data output is then sent to a PC using a wireless module. As shown in **Fig. 3**, the system starts with the user connecting/starting the PC to call the input data from the receiver. After connecting to the PC, the Delphi software will be initialized. The data received from the receiver is then displayed in the form of RR values and body temperature values, then when an abnormal value is detected (an indication of a heart attack), there is a notification in the form of a warning that will be displayed on the Delphi application.

D. Analog Circuit

An important part of this design is an analog signal conditioning circuit consisting of a summing amplifier in **Fig. 4** and an LPF filter in **Fig. 5**.

1) Summing Amplifier

The summing amplifier circuit functions as a signal amplifier so that the resulting signal is larger with a gain of 16 times.

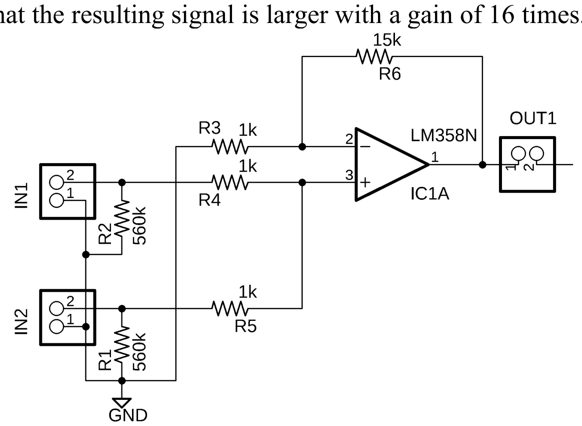

Fig. 4. Summing Amplifier

2) Low Pass Filter

The output of the summing amplifier circuit is still interfered with by high-frequency signals that are not used. Therefore, a Low Pass Filter circuit is needed.

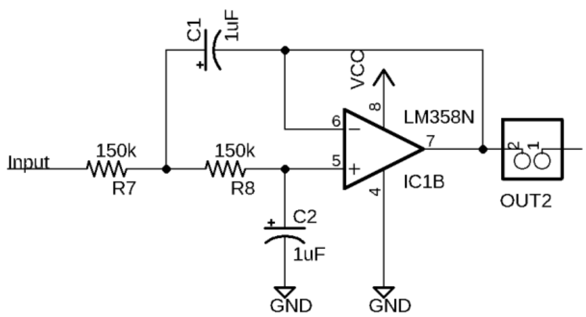

Fig. 5. Low Pass Filter

The Low Pass Filter circuit functions as a filter for the required frequency and reduces the unneeded high frequency. In this study, the Low Pass Filter circuit uses a cut-off frequency of 1 Hz.

3) Wireless Module

Wireless is a data communication media without cables (wireless). This wireless circuit uses the HC-12 module. This wireless module is used as a sender and receiver of data from the design module then the data will be displayed on a computer (PC). Requires two Tx pins to send data to the infusion pump module and Rx as a receiver, as shown in **Fig. 6**.

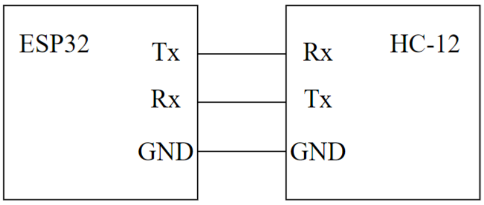

Fig. 6. Wireless Module Connection

III. Results

In this study, researchers measured the value of oxygen saturation (SpO2) and heart rate (BPM) from a respondent who was randomly selected, and the results were compared with patient monitor (BSM-2301K, Nihon Kohden, Japan) and thermometer.

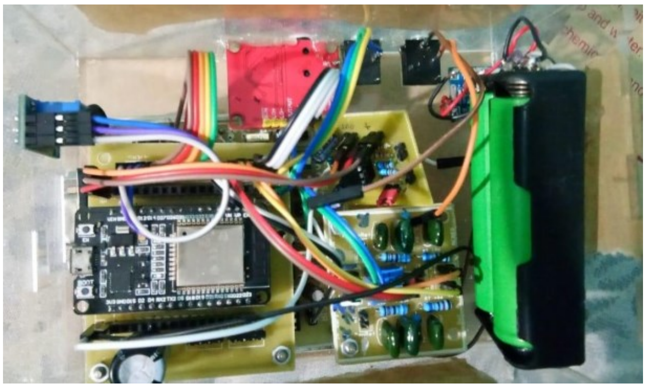

Fig. 7. The Circuit Design

1) The Circuit Design

In **Fig.7** shows the results of the circuit design. The analog part consists of an OEM ceramic piezoelectric sensor to detect the number of breaths per minute as well as a PSA (Analog Signal Conditioner) circuit consisting of a summing amplifier circuit and a low pass filter to condition the output of the sensor. The digital part consists of a DS18B20 temperature sensor, an ESP32 microcontroller and a HC-12 wireless module as a data sender and receiver, and there is a display on Delphi to display the value of respiration and body temperature.

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2) The Listing Program for Arduino

In this paper, the software was divided into two sections which are for Arduino and Delphi programming, which consisted of the respiration and body temperature data processing program and data transmission program. The respiration and body temperature data processing program was shown in **Listing Program 1**.

Listing Program: 1. Respiration and body temperature data processing program

```
LOOP:
sensorsuhu.requestTemperatures();
  suhu = sensorsuhu.getTempCByIndex(0);

  sensor = analogRead(26);
IF (refrr<=sensor) THEN
refrr=sensor;
ENDIF
ELSE THEN
refrr=refrr;holdrr=(refrr*0.6);
ENDELSE
wakturr=millis()-waktureset;
 IF (sensor>holdrr) THEN
    beat=1;
   ENDIF
 IF (sensor<(holdrr*0.9)) THEN
     IF (beat==1) THEN
     nafasmanual++;
     beat=0;
     ENDIF
    ENDIF
 IF (nafasmanual==3) THEN
     nafasmenit=180000/wakturr;
     nafasmanual=0;
     waktureset=millis();
    ENDIF
ENDLOOP
```

This study, using the HC-12 wireless system for data transmission and will be displayed on Delphi, so it requires a program for data transmission. The program used for data transmission in the form of respiration rate and body temperature values is displayed in **Pseudocode 2**.

Pseudocode: 2. Data transmission program

```
Serial.print("b");
Serial.print(nafasmenit);
Serial.print("c");
Serial.print("d");
Serial.printf(suhu);
Serial.print("f");
```

3) The Listing Program for Delphi

In Delphi programming, programs are grouped into several parts, namely: programs to display respiration and body temperature values to a PC as shown in **Listing Program 3**, and programs for notification of heart attack indications in **Listing Program 4**.

Listing Program: 3. Program to display respiration and body temperature values to a PC

```
procedure TForm1.ComDataPacket2Packet(Sender:
TObject; const Str: String);
BEGIN
Label7.Caption:=Str;
END

procedure TForm1.ComDataPacket3Packet(Sender:
TObject; const Str: String);
BEGIN
Label10.Caption:=Str;
END
```

Listing Program 3 is a data display program where the body temperature value is displayed on label 7, and the respiration rate value is displayed on label 10.

Pseudocode: 4. Heart attack indication detection notification program

```
detak:=strtoint(label4.Caption);
     spo2:=strtoint(label9.Caption);
      rr:=strtoint(label10.Caption);
suhu:=strtoint(label7.Caption);

IF (detak<60) AND (rr>0) AND (rr<12) THEN
    Label3.Caption:='SERANGAN JANTUNG'

ELSE IF (detak>100) AND (rr>24) THEN
    Label3.Caption:='SERANGAN JANTUNG'

 ELSE IF (detak>100) AND (rr>24) AND (suhu>39)
THEN
    Label3.Caption:='SERANGAN JANTUNG'

ELSE IF (spo2>0) AND (spo2<93) THEN
    Label3.Caption:='SERANGAN JANTUNG'
    ELSE
     Label3.Caption:=' ';
```

Pseudocode 4 is a heart attack detection notification program. If the parameter value meets the conditions indicating a heart attack, it will be displayed in the form of the words "SERANGAN JANTUNG" on label3.

4) The Error of Respiration Rate value

The validation of the Respiration Rate (RR) value shown in the Delphi programming was compared with the Patient Monitor. The error was showed in **Table I**.

TABLE I. THE ERROR OF MEASUREMENT FOR THE RESPIRATION RATE PARAMETER BETWEEN THE DESIGN AND STANDARD UNIT (PATIENT MONITOR).

No	Subject	Error (%)
1	P1	1.11
2	P2	4
3	P3	2.47
4	P4	0.9
5	P5	0.97

5) The Error of Body Temperature value

The validation of the body temperature value shown in the Delphi programming was compared with the thermometer. The error was showed in **Table II**.

TABLE II. THE ERROR OF MEASUREMENT FOR THE BODY TEMPERATURE PARAMETER BETWEEN THE DESIGN AND STANDARD UNIT (THERMOMETER).

No	Subject	Error (%)
1	P1	0.22
2	P2	0.39
3	P3	0.05
4	P4	0.55
5	P5	0.05

6) Heart Attack detection test result

Testing of the Heart Attack Detection System is carried out to determine whether the notification system that has been designed can function by varying the value of each parameter. The results will be shown in **Table III**.

TABLE III. HEART ATTACK DETECTION TEST RESULT.

No	Heart Rate value (BPM)	SPO2 value (%)	RR value (BrPM)	Body Temp. value (ºC)	Result
1	121	98	27	37.2	Detected
2	141	97	30	39.6	Detected
3	89	99	26	37.4	Undetected
4	80	90	19	37.3	Detected
5	45	99	9	38.9	Detected
6	119	98	19	40.1	Undetected
7	120	96	19	37.5	Undetected
8	80	99	26	39.5	Undetected
9	80	97	26	36.7	Undetected
10	80	96	20	39.3	Undetected
11	80	98	19	36.8	Undetected

IV. DISCUSSION

The design has been examined and test completely in this study and can display the value of respiration and body temperature, and there is a notification if there is an indication of a heart attack. The wireless delivery module used is HC-12. The data of respiration and body temperature values sent can be received and will be processed into Delphi software so that it can be displayed on a laptop or PC screen.

Based on the results of the respiratory circuit accuracy test by comparing the values on the design with the patient monitor shown in **Table I**, there is the largest average error by 4%. Based on **Table II**, it can be seen that the DS18B20 sensor is able to produce temperature values quite well, which can be known by comparing the values on the module with a thermometer with the largest average error of 0.55%. At a distance of one to 25 meters, data transmission without obstacles can be sent properly. From the results of the heart attack detection test in **Table III**, it can be seen that the results of the design of the detection system on the device have been functioning properly. This study is a significant improvement because in the previous study entitled Design of Vital Sign Monitor with ECG, BPM, and Respiration Rate Parameters [15], there were no notifications about heart attack detection. In a practical system, this design displays the value of vital conditions in real-time using a wireless transmission system or without using wired media as data transmission and is equipped with a notification in the event of a heart attack so that patients can be treated immediately.

Despite the increase, this study is not equipped with a respiratory signal graph, so that it is limited in displaying information. Also, this design is not supported by a data storage system, which can make it easier for doctors to view the history of respiration and body temperature values in patients and the monitoring distance is still relatively close.

V. CONCLUSION

The purpose of this study is to make a heart attack early detection device to facilitate the monitoring process for patients who have been diagnosed with heart disease so as to prevent the risk of sudden death caused by a sudden heart attack. This study has demonstrated progress for the detection of cardiac arrest by monitoring ECG and SPO2 signals, as well as BPM, SPO2, RR, and body temperature values. This study was designed using several analog circuits and ESP32 for data processing, and HC-12 for wireless data transmission, which will be sent to a PC and displayed on the Delphi application that has been made. In summary, this study has been completely tested, and the accuracy of each parameter has been proven as described.

Further experimental requests are needed to add respiration signal graphs to make it look more complex in displaying information, using a wireless transmission module that can transmit data over longer distances, and addition of a data storage system to make it easier for doctors to view the history of respiration and body temperature values in patients on an ongoing basis.

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