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Internal Control Blood pressure measurement system for the care of patients at risk of hypertension monitored by mobile application

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***Abstract*— Hypertension is a disease that causes many annual deaths worldwide, with greater affection in the elderly due to their little physical activity on a daily basis, in addition to being related to various diseases generated by obesity, as well as excessive consumption of alcohol and cigarettes, increasing the number of cases of patients with hypertension due to the confinement of COVID-19, that made people stay indoors without physical activity and increase the eating and sleeping habit, as well as the increase in sedentary lifestyle in patients with high blood pressure who cannot perform any physical activity in an energetic way because it could cause death, according to the World Health Organization (WHO) is the fourth risk factor of annual deaths, being important to diagnose patients who are at risk of suffering hypertension to prevent them from acquiring any disorder in their health. In view of this problem, in this article a blood pressure measurement system was performed for the care of patients at risk of hypertension monitored by mobile application and to know the value of blood pressure on the walls of the arteries to determine if the patient has normal or elevated blood pressure. Through the development of the system, it was observed that it works in the best way and allowed us to obtain an efficiency of 98.47%, being an accepted value for performing the process quickly and accurately.**

Keywords: Arduino UNO, Buzzer, Module Bluetooth, COVID-19, Pressure sensor, WHO, Peru, Proteus.

I. INTRODUCTION

High blood pressure is the leading cause of death in the world, responsible for 9.8 million deaths annually is worldwide [1] with about 45% of adults with elevated blood pressure [2], increasing the prevalence of high blood pressure related to body mass index, aging people and increasing obesity due to lack of physical activity, being increasingly necessary to detect, treat and control hypertension in those patients with risk factors caused by an unhealthy diet, physical inactivity, alcohol and tobacco consumption and obesity.[3]

During the confinement generated by the coronavirus pandemic (COVID-19) caused by SARS-CoV-2 [4] for being a highly contagious infection that was not controlled and spread quickly throughout the world [5], it generated that the health sector and the government decided to send all citizens to a mandatory social isolation [6], closing various public places such as schools and universities that radically changed the activities of families, teachers and students [7], changing the lifestyle of many people because they stayed longer at home and lost the mobility of moving from one place to another. Leading them to lose all physical activity, highlighting that there was a higher percentage of eating and sleeping habits than physical activity [8]. Likewise, excessive exposure to negative news, as well as saturation of the health system caused stress and anxiety in patients with high blood pressure [9]. With this confinement, exposure to sedentary lifestyle increased, making citizens prone to overweight and obesity since they did not perform any physical activity causing negative changes in cardiovascular health and increasing the cases of patients with hypertension. [10] Therefore, the lack of physical activity in people leads to vulnerable situations that cause various risk factors for multiple diseases such as cardiovascular diseases, obesity, diabetes, and some types of cancer.

On the other hand, forcing patients with hypertension to perform some physical exercise intensely, can be a cause of death, [11] according to the World Health Organization (WHO), physical inactivity is the fourth risk factor for global mortality that causes approximately 4.3 million deaths annually related to high blood pressure [12], figure that can decrease if the health of people with hypertension who cannot perform any physical activity is carefully examined, since hypertension is a disease in which the blood exerts greater pressure on the blood vessels, causing a common health problem that affects people of any age, that has no initial symptoms and can be difficult to detect as it develops over the years, causing serious health problems such as heart failure, vision loss, strokes, and complications related to kidney function.[13]

The objective of this research work is to perform a blood pressure measurement system for the care of patients at risk of hypertension monitored by mobile application and to know the value of blood pressure on the walls of the arteries to determine if the patient has normal or elevated blood pressure, So it can be diagnosed if the patient is at risk of suffering from high blood pressure and prevent them from acquiring any disorder in their health. To perform the system, the patient's arm is taken to measure two determining values, systolic pressure, and diastolic pressure, by means of a blood pressure sensor connected to an Arduino UNO programmed in Arduino IDE. Arduino IDE is a free platform that allows us to program on the Arduino card, being a friendly platform for programming because it has several libraries.

In section II, a literature review of some research papers was conducted. In section III, the methodology shall indicate the flowchart together with the electronic part of the system. In section IV, the operation of the blood pressure measurement system was performed. Section V will present the results of the system. In section VI, the discussion will be presented,

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highlighting the importance of this work. Finally, in section VII, the conclusion and recommendation will be presented.

II. LITERATURE REVIEW

Hypertension is a bad silence or that cannot be visualized to the naked eye and affects people of any age, if not treated in time can be serious for the health of the person because it leads to various diseases such as heart failure, loss of vision, among other diseases . Therefore, it is necessary to maintain the corresponding control in patients at risk of hypertension using systems that allow us to obtain accurate information about blood pressure. For example: In [14], the author mentions that hypertension is a disease that must be controlled in time since it could lead to various complications such as a cerebrovascular infarction, a heart attack, among other health problems, being necessary to perform constant monitoring with a new procedure since they currently use conventional methods of measuring blood pressure that present limitations and Disadvantages that would hinder patients at risk of hypertension, which is why it was proposed to develop a non-invasive blood pressure measurement system continuously in adult patients. The proposed method consists of using an occlude pad with latex membrane, a pneumatic circuit that will exert pressure by regulating the PWM of the solenoid valves and pump, a PIC18F2550 microcontroller to control the electronic components developed in the CCS compiler and finally developed a software to make the system a simple tool to manipulate when using the C++ programming language and the Qt interface. Obtaining as a result an efficiency of 91.25%, concluding that the development of the system performs the measurement of blood pressure in adult patients, although there were various difficulties in development, from design errors to severe limitations in materials and components.

In [15], the authors mention that blood pressure is an important disease that must be monitored frequently to effectively diagnose and prevent hypertension, since there is an increase in the rate of patients with obesity problems who are vulnerable to suffering a problem such as stroke and / or heart attack due to hypertension, But currently they perform indirect measurement of blood pressure with sphygmomanometers that are not reliable, which is why they proposed to develop a non-invasive measurement system of blood pressure in the carotid arteries. The proposed method consists of using a pressure sensor, a machine to exert pressure, a small motor, and an Arduino UNO card to control all the devices in the system. Obtaining as a result an efficiency of 93.64%, concluding that the developed system obtains accurate measurement of pressure in the carotid arteries of patients.

In [16], the author mentions that there are people who have a high consumption of foods with high levels of sodium that causes elevation of blood pressure, about 35% of patients with high pressure when consuming these foods suffer from alteration in their physical condition such as their heart rate, body temperature and blood pressure, Making them prone to heart attack, which is why he proposed to develop a wireless system for measuring, analyzing and controlling blood pressure. The proposed method consists of using a heart rate sensor, an LM35 sensor to measure temperature, an ESP8266 Wi-Fi module and an Arduino NANO card to control the electronic components. Obtaining as a result an efficiency of 92.89%, concluding that the system analyzes and controls blood pressure in patients with high consumption of foods with sodium visualizing their health condition.

In [17], the authors mention that there is currently an increase in people suffering from high blood pressure, caused by high cholesterol, obesity, excessive consumption of smoking, etc., being necessary to diagnose these patients with hypertension to maintain adequate control and prevent them from suffering from cardiovascular disease or presenting difficulty breathing causing death, That is why they proposed to develop a blood pressure monitoring system for older adults suffering from high blood pressure, using SDK sensors and cloud storage. The proposed method consists of using a pulse sensor, a PPG sensor, the Microsoft Visual Studio code compiler, and an Arduino UNO card together with a Shield ethernet module. Obtaining as a result an efficiency of 95.33%, concluding that its system allows to monitor in the best way the possible elevations of blood pressure in older adults to prevent any difficulty in their health.

In [18], the authors mention that blood pressure is an important factor as an indicator of the patient's health status, since it could cause cardiovascular disease that is one of the main causes of death in industrialized countries when they have high blood pressure values, which is why they proposed to develop a continuous blood pressure measurement system for patients with hypertension. The proposed method consists of using a pulse sensor, a PIC 18F4550 microcontroller, a MySQL database and an LM35 temperature sensor. Obtaining as a result an efficiency of 90.47%, concluding that his proposed system presents a new method for measuring blood pressure in patients with hypertension.

III. METHODOLOGY

In this part, the flow diagram of the blood pressure measurement system for the care of patients at risk of hypertension was elaborated, describing the complete operation that the system will have so that it performs the measurement accurately and can classify the patient according to the measured value.

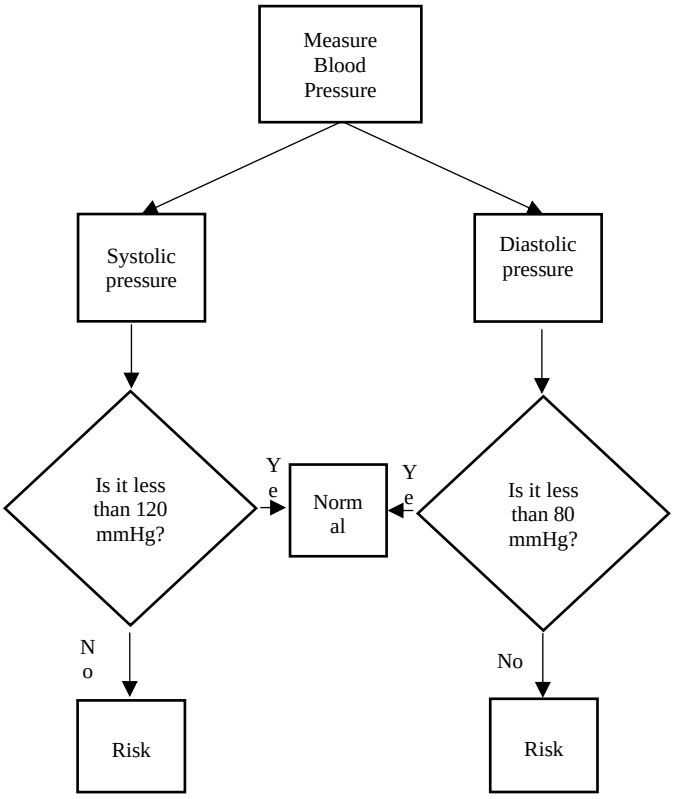

Fig. 1. Arterial Reaction System Flowchart

Once the flow chart of the system is specified, then the electronic part will be mentioned, which is a fundamental part that will allow the measurement of the blood pressure of the patients.

A. *Arduino UNO*

Arduino UNO is a microcontroller that will be responsible for reading the values of blood pressure that will be recorded by means of an analog sensor, for this reason, it was necessary to use this Arduino UNO card since it has 6 analog input pins and 14 digital pins that facilitates n The reading of the blood pressure meter sensor, as shown in Figure 2. The programming of this card was conducted on its free platform called Arduino IDE and to this add all the libraries that this platform has, facilitating programming.

Fig. 2 Arduino UNO Microcontroller

B. *Sensor FPN-07PG*

The FPN-07PG sensor, as shown in Figure 3, is a sensor that is used to measure blood pressure in patients at risk of hypertension, its operation in the measurement system is mainly based on receiving the relative pressure in the cuff, which is why the location of this blood pressure sensor It should be placed in a position close to the cuff to perform the measurement of blood pressure.

The internal operation of the FPN-07PG sensor is based on transforming the air tension into an electrical signal through several internal resistive elements. While it is true, the FPN-07PG sensor can be replaced by another electronic component s of similar characteristics, but this FPN-07PG sensor has important features that are fundamental for this blood pressure measurement system that are: pressure, transfer faction(mV/mmHg) and measurement [19].

Fig. 3 Pressure sensor FPN-07PG

C. *Bluetooth module HC-05*

The HC-05 Bluetooth module, as shown in Figure 4, is an electronic device that supports wireless connections via the Bluetooth protocol. Este device can behave as master or slave, likewise, it facilitates the connection with any mobile device or PC wirelessly with ease of operation, in addition to the connection of this electronic device with Arduino UNO is practical.[20]

Its operation of the HC-05 Bluetooth module is based on allowing the connection of the blood pressure measurement system with the patient's mobile device wirelessly, so that the value of the patient's blood pressure measurement can be displayed through a mobile application developed for any device Android, covering a distance of up to 10 meters between the blood pressure measurement system and the patient's mobile device.

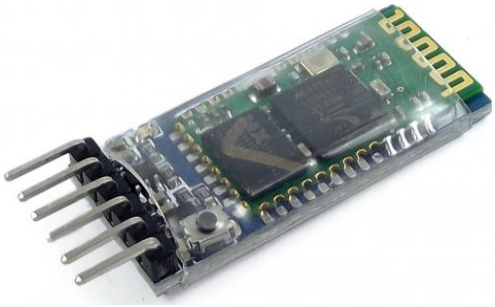

Fig. 4 Bluetooth module HC-05

D. Active buzzer

The active buzzer, as shown in Figure 5, is an important electronic component for the blood pressure measurement system, as it will emit sound at a certain frequency when it detects that the patient's blood pressure value is out of range. Automatically, therefore, it serves as a signaling or warning mechanism and is commonly used in various systems that require alerts.

The active buzzer will notify the personnel in charge of manipulating the blood pressure measurement system through the emission of a sound at the moment in which the system detects the person, likewise, it will emit a sound when the system is correctly linked to the mobile device through the Bluetooth module, also the System will emit a sound When the pressure sensor detects a value outside the normal range, all that procedure will perform it automatically.

The active buzzer is an electronic component that unites with direct current from 4v to 8v, in addition, it has a resonant frequency of approximately 2.3 KHz.[21] It is known as active because it has internal components that generate the electrical signal at audible frequencies, so the signal controlled by the active buzzer can be digital.

Fig. 5 Active buzzer

IV. OPERATION OF THE MEASUREMENT SYSTEM

In this part we design the blood pressure measurement system for the care of patients at risk of hypertension monitored by mobile application to find the value of blood pressure in patients, as shown in Figure 6, with the use of a set of electronic devices that They will allow us to evaluate the patient and evaluate if he is at risk of hypertension.

Fig. 6 Measurement system design

Likewise, the simulation of the blood pressure measurement system for the care of patients at risk of hypertension monitored by mobile application in the Proteus software was carried out to simulate in real time the management of the complete system, as shown in figure 7, where it is observed that through the Arduino UNO will be sent a PWM signal to command the DC motor to start inflating the cuff with air that is placed on the patient's arm. After inflating the fabric cuff, pressure is exerted on the patient's arm and with the help of the FPN-07PG blood pressure sensor the corresponding measurements will be made and visualized through a mobile application.

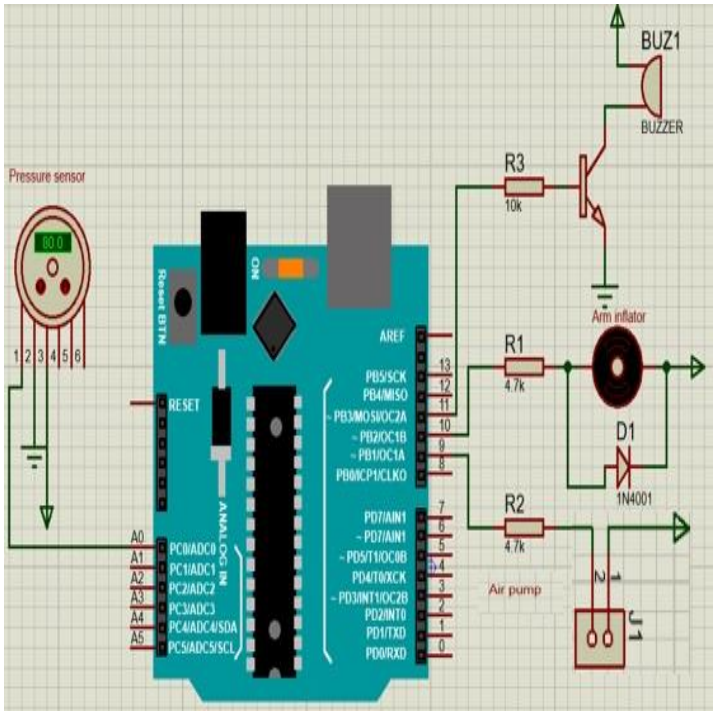

Fig. 7 System simulation

The system will perform two corresponding measurements on the patient, the first measurement is the systolic pressure that is determined with the first pulse detected by the pressure sensor, the second measurement is the diastolic pressure that is determined with the last pulse detected by the pressure sensor. If both values are in the normal range the patient is stable, otherwise, the patient could be at risk of hypertension if the measurement values are out of range.

In order to visualize the values of systolic pressure and diastolic pressure, a mobile application was developed for any Android device, as shown in figure 8, using App Inventor as a tool, which is a platform that allows us to develop mobile applications in a very practical way using internal block diagrams And it allows us to connect with mobile devices by using Bluetooth. With this mobile application you can display the values of the pressure sensor about the systolic pressure value as the diastolic pressure value.

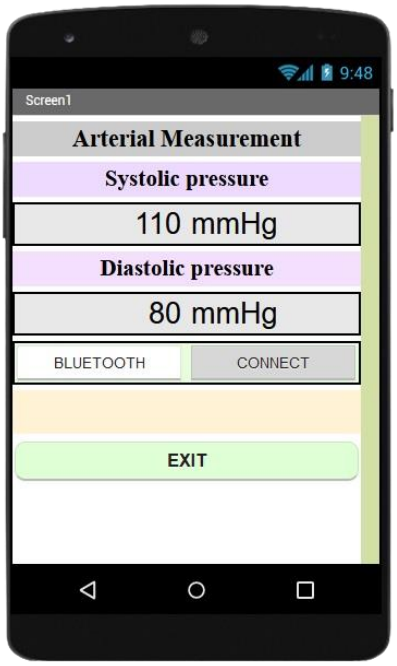

Fig. 8 Mobile App

In Figure 8, the value of systolic pressure and diastolic pressure of a patient with normal blood pressure detected by the pressure sensor was observed.

V. RESULTS

With the development of the blood pressure measurement system, the objective of knowing the patient's blood pressure is met to classify it according to the reading of the pressure sensor that is displayed through the mobile application . With this, it would be given notice if the ancient may be at risk of high blood pressure, preventing you from suffering from any cardiovascular problem or disorder that complicates your health.

Table I shows the characteristics of the blood pressure measurement system. As specified above, the system complies with each parameter specified throughout the article so that it can perform its function correctly, resulting in a very useful system to be able to know the value of the blood pressure on the walls of the arteries to determine if the patient has normal or elevated blood pressure, So it can be diagnosed if the patient is at risk of suffering from high blood pressure and prevent them from acquiring any disorder in their health.

TABLE I. CHARACTERISTICS OF THE BLOOD PRESSURE MEASUREMENT SYSTEM

Blood pressure measurement system	
Systolic pressure	Normal: ≤ 120 mmHg High: > 120 mmHg
Diastolic pressure	Normal: ≤ 80 mmHg High: > 80 mmHg
Measuring point	Arm
Time	8 seconds

By implementing this system, it will be possible to know the measurement of the blood pressure of any patient with greater accuracy, using low-cost electronic components with precise characteristics for the correct measurement of the patient's blood pressure. The time it takes to perform the measurement of blood pressure in the patient is 8 seconds, being a system that shows the values of the measurement early.

To develop the blood pressure measurement system for the care of patients at risk of hypertension monitored by mobile application, the algorithm shown in Table II was used, specifying each internal process carried out by the system to carry out the measurement of blood pressure, allowing us to obtain an efficiency of 98.47% in its operation, being an accepted value since it performs the whole process quickly, accurately and automatically unlike the instrument and sphygmomanometer that is commonly used in most health centers.

TABLE II. SYSTEM ALGORITHM

Algorithm 1 Blood pressure measurement
1 placing the fabric cuff on the patient's arm.
2 linking the system to the mobile device via the Bluetooth module.
3 while fabric cuff is on the patient's arm.
4 do blood pressure sensor will perform blood pressure measurement
5 display the values obtained through the mobile application
6 end while
7 if the patient has out-of-range values
8 system will indicate that the patient is at risk of hypertension.
9 will generate an alert through the active Buzzer.
10 end if

For the implementation of the blood pressure measurement system for the care of patients at risk of hypertension monitored by mobile application, all the components mentioned throughout the article must be available. These tools were considered for their correct functioning in the analysis of the system. It should be noted that the importance of this system is that it does not present any problem in its operation for any medical center that requires to implement it, since it will allow to have the complete information of the blood pressure of each patient to determine if he may be at risk of suffering hypertension.

The location of the fabric cuff influences the measurement of blood pressure; therefore, it must be placed on the upper arm without any garment above the elbow so that the sensor can make a correct reading and can be viewed through the mobile application of the patient or doctor.

This system can be used by all medical centers, as well as it can be used by patients to measure their blood pressure accurately and be alert if they have abnormal values so that they can go to the doctor immediately.

VI. DISCUSSION

Today there are many research papers related to blood pressure that try to provide information about the values of the pressure to determine if the patient may suffer from a serious disorder that significantly increases the possibility of acquiring other diseases that complicate their health.

Likewise, this research work meets its development objective , helping to prevent the patient from presenting and risk suffering from hypertension and not acquiring any disorder in their health. On the other hand, this system has differences with other research works developed, for example, the work done by [14], where the author preprocessor develops a non-invasive blood pressure measurement system continuously in adult patients. Where he obtained a result of 91.25% efficiency, but the author did not evaluate his system correctly because the values obtained from the measurement vary because of its pneumatic circuit that exerts pressure on the arm, so it is not a safe measurement.

We also have the work developed by [15], where the authors proposed to develop a non-invasive measurement system of blood pressure in the carotid arteries. Where they obtained a result of 93.64% efficiency but did not perform the corresponding tests of the measurement in patients, so this system obtained that efficiency based on simulation and its real operation in patients would not be dependable at the time of measuring blood pressure.

We also have the work developed by [16], where the author proposed to develop a wireless system for measuring, analyzing, and controlling blood pressure. Where they obtained a result of 92.89% efficiency, but this system when using the LM35 temperature sensor presents a higher level of error when comparing with the real value, in addition to presenting greater sensitivity due to environmental factors, being able to measure another value different from the real one so this system is not at all dependable.

We also have the work developed by [17], where the authors proposed to develop a blood pressure monitoring system for older adults suffering from high blood pressure, using SDK sensors and cloud storage. Where they obtained a result of 95.33% efficiency, but this system is completely vulnerable in the security of the database, in addition to the sensor used in the system for pressure measurement is very sensitive to any movement that the patient may have.

We also have the work developed by [18], where the prop authors used to develop a continuous blood pressure measurement system for patients with hypertension. Where they obtained a result of 90.47% efficiency, but this system does not efficiently monitor patients, in addition to its cloud storage cannot register patients who do not present hypertension, being a limited system for all people. Likewise, its LM35 temperature sensor has a higher percentage of error and sensitivity due to environmental factors.

We also have the work developed by [22], where the authors proposed to develop a blood pressure measurement system with cuff (a), which has its own parameters unlike our proposed system (b), as shown in Table II.

TABLE III. COMPARISON OF MEASUREMENT SYSTEMS

	to	b
Methodology	Manual	Automatic
Measures considered	Normal	Systolic and Diastolic
Measuring range	Not specified	Specifies for systolic and diastolic pressures
Place of measurement	Arm	Arm
Measuring time	30 seconds	8 seconds
Accuracy	9 0.11%	98,47%

VII. CONCLUSION AND RECOMMENDATION

It is concluded that the system develops in the best way, performs the measurements accurately and evaluates whether the current may be at risk of hypertension automatically. With this, the system helps to prevent the patient from avoiding and acquiring any disorder in their health, highlighting that it only takes 8 seconds to perform the measurement of blood pressure.

It is concluded that the system is completely safe for the person who sends it, as well as for the person who will be measured accordingly since it is only necessary to see if the patient is well otherwise an alert is not doctors for evaluation.

It is concluded that the system performs the measurement of blood pressure instantaneously, so it would help prevent patients from causing crowds within the health center, preventing them from catching any virus such as COVID-19 that has not yet disappeared from our environment and that the corresponding measures must be taken.

It is concluded that the implementation of the blood pressure measurement system for the care of patients at risk of hypertension monitored by mobile application is not complicated and is useful for anyone who suffers from cardiovascular disease and intends to measure their blood pressure frequently and without any inconvenience.

It is concluded that the system can be developed in various places, its operation will always be optimal and efficient. With this, the system would be of great contribution to the health area because it would not present any limitation in its operation when taking blood pressure measurements instantaneously.

As future work, a database for the storage of blood pressure measurements will be added to the system, as well as a GSM/GPRS module to establish communication with a nearby health center in case of an emergency by the patient.

It is recommended that this system can perform the measurements of patients in the part of the arm without any garment so that the sensor makes a correct reading and can be diagnosed if the patient may suffer from hypertension.

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