PORTABLE SMART MINI PATIENT MONITOR FOR IMPROVED HEALTHCARE OUTCOMES: PATIENT-BASED CARE DEVICE

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ABSTRACT: This study aims to present the prototype for Portable Smart Mini Patient Monitor for improved healthcare outcomes and patient-based care that records and displays the vital physiological signs including heartbeats, body temperature, ECG, and SPO2. The device has designed with multiple sensors connected with Arduino UNO and interfaced with an LCD display that provide real-time acquisition of the patient's data. The recent era of medical advancement and digitization has embarked on the need for efficient and innovative medical devices that provide better admittance to competent and dynamic patient care like the smart mini patient monitor to facilitate substantial diagnosis and treatment of patients' medical diseases by accurately identifying the pattern and effect of the ailment along with the improved patient experience and healthcare outcomes. The research aims to provide better healthcare opportunities to the patients on daily bases and improve the overall healthcare delivery system and make it work simultaneously with the increased population yearning for medical attention. The smart mini patient monitor was used for the detection of vital signs for five human subjects. The acquired results were then calibrated with a thermometer and BIOPAC device. The main idea of the study dwells upon the incorporation of multiple sensors into one portable device that yields multiple physiological signals at one time with utmost precision and can be easily tracked, stored, and used for medical diagnosis.

Key words: Patient monitoring, portable sensors, ECG, heartbeats, body temperature and SPO2.

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INTRODUCTION

The composition and size of the world populace have taken a drastic change over the last decade, thus the recent demographic trends in the world demand substantial implications for the healthcare industry for improved healthcare and advancement to facilitate the dramatic increase of population subjected to treatment and healthcare requirements. The medical practitioners and engineers are striving to make healthcare and biomedical devices more advanced, digitized, and portable to be at par with the requirements and needs of the patients. Innovation has become a fundamental and vital segment in cutting edge living and impacts the manner by which we as a whole live and work. Previously, a similar device by Teja *et al*., (2018) was constructed that is semi-portable and constantly checks the patient's health parameters. This smart ECG can be worn and has simple functions that can be monitored and performed by the patients in real-time. Healthcare professionals can use their smartphones to access patient data wirelessly in real-time. Similarly, Checkme, a device able to detect vital-signs, was constructed to increase routine patient monitoring by reducing testing time, variations, and inappropriate inputs throughout the Electronic Health Record (EHR) (Weenk *et al*., 2018). They tested the reliability of patient self-measurements using the Checkme compared to world standard and nurse tests. The study showed the data analysis of the fifty patients onto which the time-related evaluation sessions were performed randomly. Patients can easily and accurately measure their vital signs on their own by checkme device. This could save nurses time and avoid mistakes by entering data manually in the EHR. Presented by (Koshti *et al*., 2016), a modern, user-friendly system was designed to track the Lead I electrocardiogram (ECG) signal easily and non-invasively using a wireless steering wheel. The embedded application server program is the fusion of the internet and embedded device technologies. People can access their devices remotely through this embedded web server. Based on the wavelet's continuous transformation, a new heart rate control method was introduced. Electrodes have been used to monitor skin voltages to control heart rate. To amplify the signal, the registered voltages are sent to an amplifier and then go to a filter to eliminate the noise. According to the study presented by (Uysal *et al*, 2016) using Bluetooth enabled WSN; a device for monitoring heart rate was developed. Using the HC-05 Bluetooth module also processed on PC, SPO2 data

obtained from patients is transmitted wirelessly to the personal computer via Arduino. GUI has been created and utilizes this with MATLAB programming without programming information, while permitting constant perception of pulse beat estimations.

Generally, innovation has a positive effect as its causes us to oversee and control our everyday schedules. Nonetheless, current innovation has a significant task to carry out in different areas, for example, beating the numerous difficulties confronting wellbeing and social consideration. To conquer these difficulties, the far-off ongoing checking of an individual's wellbeing can be utilized to recognize backslides in conditions, accordingly, empowering early mediation (Ventola, 2014). For this purpose, the current study attempts to introduce a novel medical device namely 'Smart mini– Patient Monitor' and discusses its construction and working mechanism along with its physical features including portability, smart interfacing, and precision. The usually accessible patient screens in the market shows ECG of the human heart, temperature of human body and oxygen immersion level of the blood and the soundness of a patient can be checked ceaselessly by noticing the showed readings without actual communication. This sequence of observed parameters aids in predicting the disease status (Kadhim,2020) but in general the economical range of them are considerably large sized monitors approximately equal to the size of desktop screen suggested system. The smart mini patient monitoring system is designed to monitor the vital physiological signs including heartbeats, body temperature, Electrocardiogram (ECG), and peripheral capillary oxygen saturation **(**SPO2). The device is constructed with multiple sensors connected with Arduino UNO and interfaced with NOKIA_5110 LCD. The novel intervention in the smart mini patient monitor is the smartphone interfacing that aspires to provide patients with 24x7 accessibility to their physiological conditions, keeping them informed and aware of their medical conditions at all times. This particular study includes the methodical approach, instruments, and accessories used to design the smart mini patient monitor along with the software that is used to apprehend signals and interfacing of the retrieved data. The smart mini patient monitor is believed to have immense potential and credibility to improve and enhance the current healthcare system by providing the patients with real-time monitoring of their vital signs with the most portable design and easy mechanism. our real aim was to introduce a system which allows the patient's vitals to be viewed at monitor's screen as well as at the cell phone of doctor and attendance. The main objectives for constructing the smart mini patient monitor are to Provide the healthcare system with portable and advance medical assistive devices to Improve overall patient care and healthcare opportunities for the patients. Incorporate different detection parameters into a single multi-functional medical device. The main materials of manufacturing equipment in the past were based on single parameters. Nowadays multipurpose patient monitors are commonly used namely single and multiple parameter systems. The monitoring system with a single parameter is used to measure blood pressure, spO2, ECG, etc. separately while a multiple parameter patient monitoring system receives and shows multiple parameters simultaneously (Wan, J. *et al*, 2018).

MATERIALS AND METHODS

Methodology techniques to developed this device by connecting multiple sensors (sensing body parameters) with Arduino UNO and interface Arduino UNO with LCD Nokia_5110, to analyze result. These readings will also be shown on the Android App, thus providing you with the basic medical record at your disposal and this device also provide telecommunication. All the data of this device is stored in smart device where app is installed, so that anyone can easily get their medical record at any time. There will not be any need of visiting physicians for examining such parameters or carrying multiple devices for such purpose. We have put certain coding in our programing for the calculation of parameters that are interlinked with each other.

This device read the number of heartbeats, body temperature, SPO2, and ECG. These readings shown on the smartphone app as well as LCD thus providing you with the basic medical record at your disposal. There are not be any need of visiting physicians for examining such parameters or carrying multiple devices for such purpose. MIT App inventor used for application development and used coding in our programming for the calculation of parameters that are interlinked with each other. The detailed description of the materials used is given below:

Nokia 5110 LCD: The Nokia 5110 is an alphanumeric screen, initially proposed to be utilized as a phone screen. It can be easily mounted to the PCB. It has a built-in controller namely the PCD8544 controller that is a low power CMOS LCD driver, intended to drive a realistic presentation of 84 columns and 48 rows. The reason behind using this LCD is because it carries all the necessary functions in one chip, comprising of bias voltages, real-time generation of LCD supply, resulting in minimum utilization of the external components with relatively low power consumption that lowers the complexity of the project and increases the efficacy. The PCD8544 controller easily interfaces interfaced with Arduino. It also supports the graphics of bitmap images.

AD8232 ECG Sensor with Electrodes: This main reason to use this sensor is its cost-effectivity and accuracy to calculate the electrical activity of the heart. The ECG sensors amplify the electrical signal/activity

through the electrodes. The signals are then charted as ECG and deliver the output in and as analog readings (Prasad & Kavanashree, 2019). The signals from the Electrocardiogram can turn out to be noisy, in such cases, the single lead heart monitor works as an operational amplifier for noise cancellation and assists in obtaining a clear signal throughout the QT and PR monitoring intervals.

The AD8232 serves as a unified signal acquisition medium for ECG signals and various bio-potential measuring applications. It is primarily designed to filter, extract and amplify bio-signals in the presence of noise caused by motions or remote placement

The AD8232 module comprises 9 connections and offers essential pins for monitor operations while connected to the Arduino UNO. Moreover, the module contains RL and RA (left leg and right arm), and LA (left arm) pins to connect the custom sensors to the module. In addition to the pins, the module also comprises an associated semiconductor diode indicator that pulsates the heart-beat rhythm.

MAX30100 Pulse Oximeter: MAX30100 is pulse oximetry integrated into the internal system of the smart mini patient monitor as it offers low-noise signal processing of analog data. The I2C digital interface of the pulse oximeter is devised to interconnect with the host microcontroller i.e., the Arduino UNO. MAX30100 consists of an oximetry subsystem with the technology of ALC (ambient light cancellation), discrete-time filter, and 16-bit delta analog to digital converter (Strogonovs, 2017). It runs on a low-power operation that makes it suitable to be used for battery-operated systems like the one present in our device.

LM35 Body Temperature: The LM35 is a temperature indicating an integrated circuit device. The output voltage of the LM35 is linearly proportional to the temperature in centigrade. It is best suited for portable devices like the smart mini patient monitor as it does not involve any external calibration or setting. The LM35 is used to signalize body temperature.

HC-05 Bluetooth Module: HC-05 module is a Bluetooth SPP (Serial Port Protocol) unit (Sharma & Anand, n.d) incorporated into the smart mini patient monitor as it provides transparent set-up via wireless serial connections. It has built-in CMOS technology that provides CSR single-chip system with AFH (Adaptive Frequency Hopping) function making signal processing more effective and precise for the project (Chawla, 2015).

Arduino Integrated Development Environment (IDE): The explanation behind utilizing the Arduino Integrated Development Environment (IDE) is its cross-stage perspective including the capacities procured from C and C++. It functions as a middle person by means of which the projects and codes are composed and transferred to Arduino viable sheets. The Arduino IDE contains uncommon code organizing that upholds C and C++ programming dialects that empower the clients to coordinate their tweaked programs/codes into the microcontroller. The clients are likewise profited with a coordinated programming library in the Arduino IDE that gives regular yield and info systems.

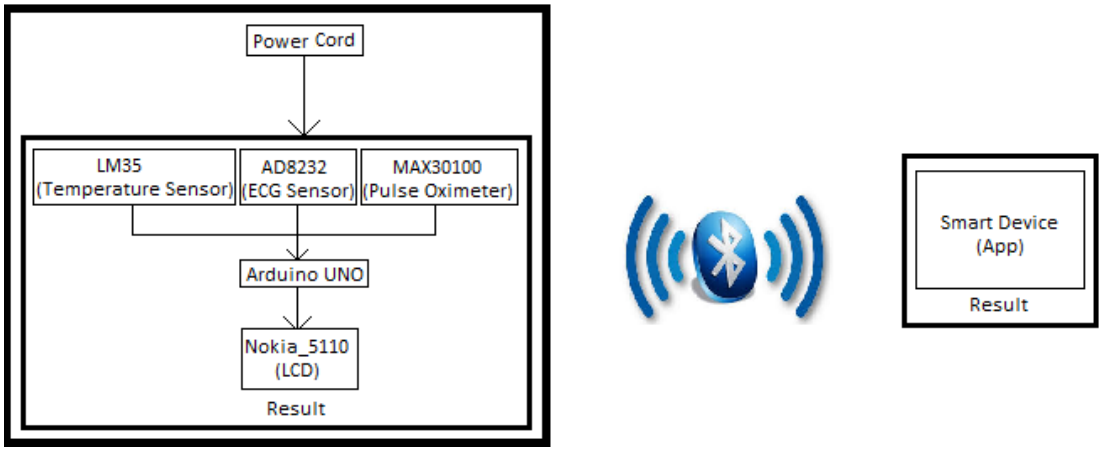

Figure 1. Block Diagram of Project

Figure 1 is the block diagram of smart mini patient monitors in which LM35 (temperature sensor), Ad8232 (ECG sensor) and MAX30100 (Pulse Oximeter) are connected with Arduino UNO which is interfaced with Nokia _5110 (LCD) on which results could be analyzed. Hardware is powered by power bank. The device is also interfaced with smart device via Bluetooth so the results of these sensors can also be shown on App installed in smart device. Readings of all sensors are also stored in smart device.

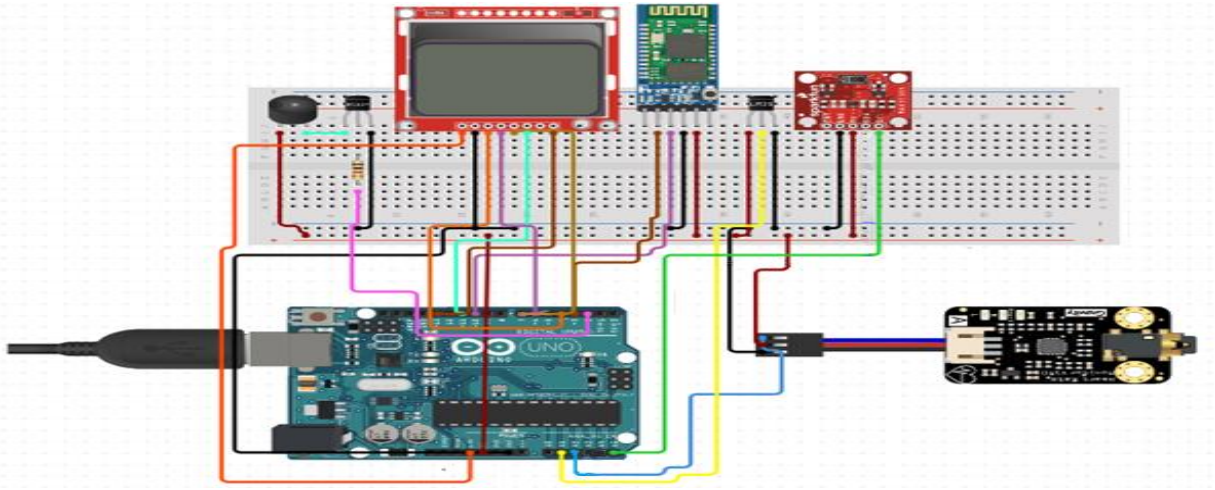

Figure 2. Schematic Diagram of smart mini patient monitor

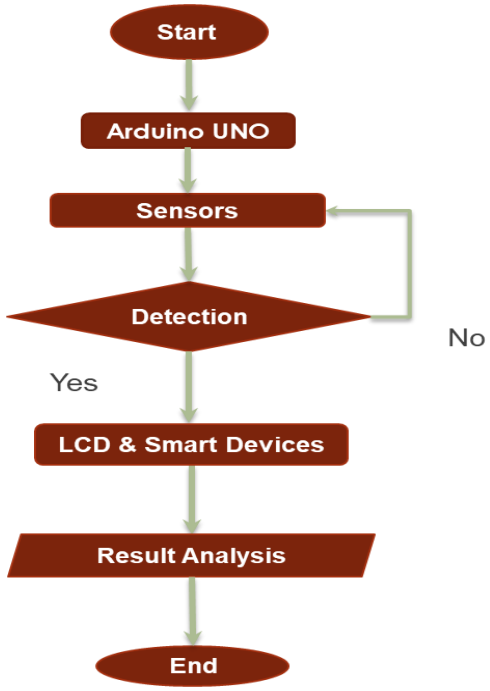

Figure 3. Flow Chart of a Device

Figure 2. and Figure 3. shows the flow of our project, as the device starts, multiple sensors those are connected with Arduino UNO detect body parameters including beats per minute, body temperature, peripheral capillary oxygen saturation **(**SPO2) and electrocardiogram ECG wave. If in any case the sensors fail to detect these parameters, then the detection again takes place and if the detection becomes successful then this detection goes to device LCD and also on Smart Device from where we can analyze our result.

RESULTS

The clinical trial was conducted on five human subjects for the data collection. The results are exhibited in Figure 4. The device was turned on and was paired with the Bluetooth device of the cell phone. Patient's demographics and readings for vital parameters were taken thus 20 measurements were taken from 5 subjects. Simultaneously the measurements were compared with the BIOPAC device and thermometer.

The above-mentioned Figure 4. and Figure 5. show the Arduino sample code that is generated to acquire signals from the different sensors used in the project namely AD8232 ECG Sensor, MAX30100 Pulse Oximeter, and LM35 Body Temperature that is projected on the LCD screen for the display.

Figure 7. The Nokia 5110 is an alphanumeric screen, initially proposed to be utilized as a phone screen. It can be easily mounted to the PCB. It has a built-in controller namely the PCD8544 controller that is a low power CMOS LCD driver, intended to drive a realistic presentation of 84 columns and 48 rows. The reason behind using this LCD is because it carries all the necessary functions in one chip, comprising of bias voltages, real-time generation of LCD supply, resulting in minimum utilization of the external components with relatively low power consumption that lowers the complexity of the project and increases the efficacy. The PCD8544 controller easily interfaces interfaced with Arduino. It also supports the graphics of bitmap images.

All the experiments that are done in order to obtain results. Multiple readings were taken on SmartCura device from non-critically ill human subjects to determine 4 of the vital signs necessary for early warning. After performing the first run subjects were able to acquire their vital signs easily. The results obtained from SmartCura were highly comparable to BIOPAC device.

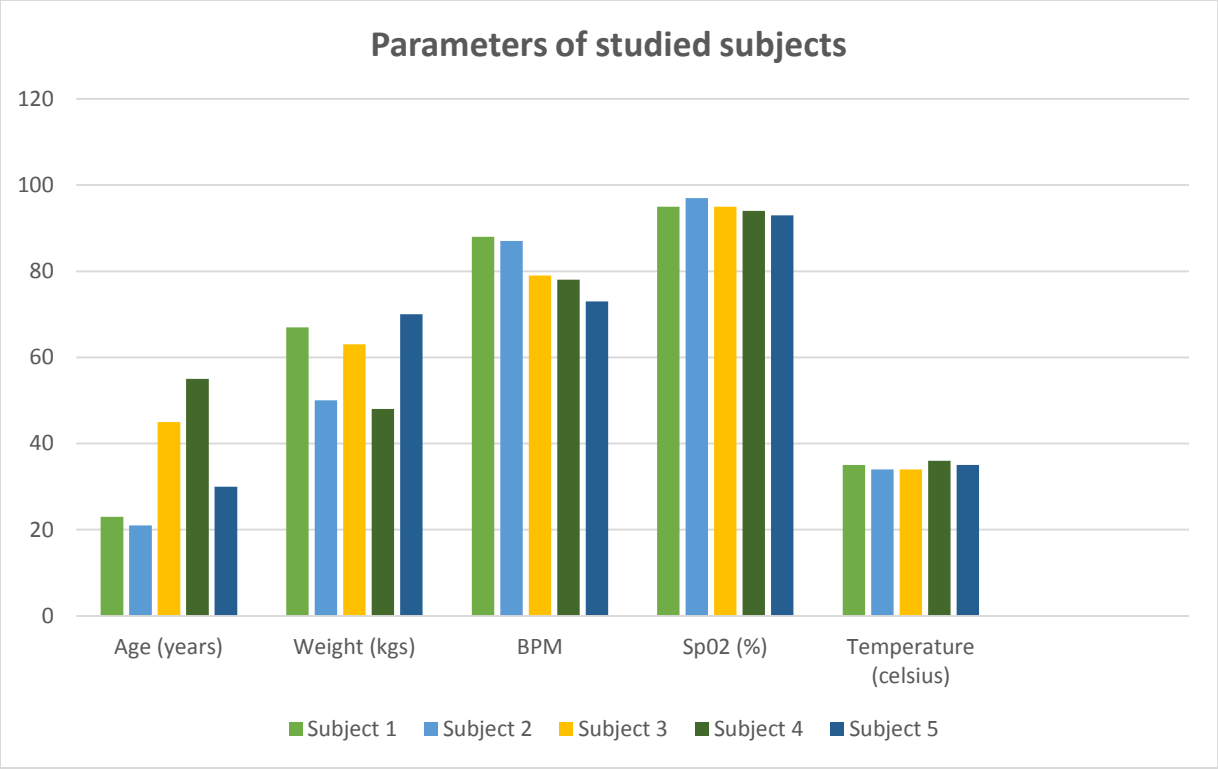

Figure 4. Statistical Analysis of five persons for five parameters

Figure 5. Arduino UNO code for Smart Mini Patient Monitor

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```
const int LM35_sensor=A2;
float tempc; //variable to store temperature in degree Celsius
float tempf; //variable to store temperature in Fahreinheit
float vout; //temporary variable to hold sensor reading
/////////////////////////////////////////// THERMISTOR ////////////////////////////////////////////////////

uint16_t Temp, Hrate, SpO2, EcgReading, EcgPlotX;
int EcgPlotY, ECGmin, ECGmax;
uint16_t ECG_ARRAY[84];

////////////////////////////////////////////////PulseOximeter////////////////////////////////////////////////
// PulseOximeter is the higher level interface to the sensor
// it offers:
//  * beat detection reporting
//  * heart rate calculation
//  * SpO2 (oxidation level) calculation
PulseOximeter pox;

uint32_t tsLastReport = 0, ECGlastRepTiem = 0, AppupdateTime = 0;

// Callback (registered below) fired when a pulse is detected
void onBeatDetected()
```

Figure 6. Arduino UNO code for Smart Mini Patient Monitor

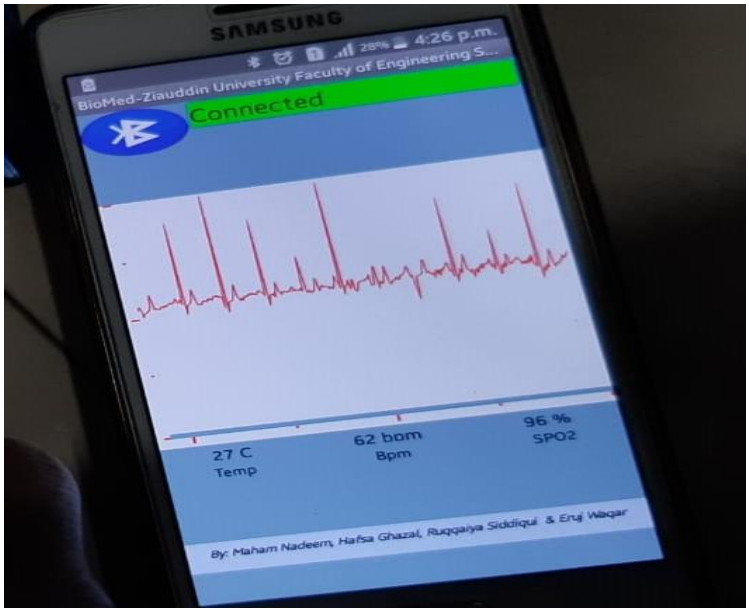

Figure 7. The ECG acquired of the subjects display on the cell phone

DISCUSSION

It concludes all the experiments that are done in order to obtain results. Multiple readings were taken on SmartCura device from non-critically ill human subjects to determine four of the vital signs necessary for early warning. After performing the first run subjects were able to acquire their vital signs easily. The results obtained from SmartCura were highly comparable to SmartCura device. Our temperature sensor is showing fluctuation when compared to conventional thermometer. The device is showing best results in supine position. Cardiac patients can use SmartCura device for 24 hours ECG

monitoring and analysis. This method will be comfortable rather than having Holter monitors all around. However, critically ill patients cannot take their own readings. Further clinical researches should focus on using SmartCura device to predict the diseases indicated by the abnormalities vital signs are showing and feedback of the device users. It is suitable for home monitoring and prevention of complications and fast recovery of pre-habilitated patients. The patient does not need multiple devices to measure multiple vital signs but with this portable all in one device can do it at once, whose measurement is comparable to other digital and conventional devices. However, temperature sensors reading is the only limitation. The utilization of mobile telephones for data acquisition and storage is widely accepted in the current digitized sector of the healthcare system as it assists in providing fluent connectivity and access for the medical practitioners to track different signals through different interfaced sensors. This reduces the need for constant assistance from a human helper according to (Pigadas *et al*., 2011), for example, caretakers and nurses for patients who are elderly, living in remote areas, or with a physical disability.

The smart mini patient monitor achieves the following objectives:

- Better and improved access to efficient patient care by integrating useful protocols relating to patient care.
- Precise and substantial analysis of patients by recognizing the vital signs through the smart mini patient monitor.
- Valued and advanced healthcare attention and treatment to the patients.
- Improved technology and assistive devices to conduct an appropriate assessment for preliminary treatment.
- The overall growth and success in delivering quality care and consideration to the patient.

Further research is needed to provide iOS App so that parameters readings can also show on iOS as well as Android. According to availability of1 sensors or development in biomedical trend more parameter can be sense and monitor which will drastically improve the efficiency of the wireless monitoring system in biomedical field.

Conclusion: It is obvious identifying the opportunities and challenges of mobile technology and reducing barriers, strengthening the positive points will have a significant role in the appropriate planning and promoting the achievements of the health care systems based on mobile and helps to design a roadmap for improvement of mobile health This prototype of smart patient monitor has developed, utilizing wireless sensors to the base. The gadget is versatile, conservative and hand held. The outcomes acquired from the venture show that the aim of the project has been accomplished. A correspondence has been created among sensors and Arduino UNO. Arduino processes the data and display on the screen while Bluetooth transfers the similar data to the mobile app as connection is made when Bluetooth are paired. These vital signs can be measured anywhere and anytime.

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