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Monitoring Patients to Prevent Myocardial Infarction using Internet of Things Technology

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ABSTRACT

Introduction: The Iranian Ministry of Health has announced that when a heart attack occurs, 50% of patients die within the first hours after a heart attack. The purpose of this article is to provide a system for 24-hour patient monitoring, prevention of heart attack and reduction of mortality.

Methods: In this original research study, by reviewing the valid articles of 2020, two sensor samples with the least error, fast and user-friendly were selected, then presented by new system methods including two-phase: warning transmission and normal mode. Received information from both of the phases is stored in the patient's digital file. Based on this information, personalized decisions can be made for each patient.

Results: According to the Iranian Ministry of Health and Medical Education, more than 40% of deaths in the country are related to the heart diseases, 19% of them are related to the heart attack, while 50% of deaths due to myocardial infraction happen in the first hours. Our proposed 24-hour monitoring system, using the most up-to-date and accurate measurement tools, reduces the risk by continuously measuring the patient's vital signs.

Conclusion: In our proposed system, the time and numerical interval of each measurement by the sensors are determined by the respective doctor, then the information is stored in each person's digital medical record. This system helps prescribe medication and make more accurate decisions based on the patient's specific circumstances. It is recommended that the drug delivery phase be performed within the arrival time of the medical team to minimize the risk.

Keywords: Internet of medical things, Blood sugar, Myocardial infarction, Continuous monitoring, Sending warning messages.

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Introduction

The present research using the Internet of Things can help prevent heart attack and its irreversible risks by monitoring the patient and alerting the biomedical sign fluctuations to the medical team. One of the main and significant pillars in this system is time, so tools and technologies with the lowest time delay were used. Also, energy consumption is minimum and in line with other system objectives.

In this system, we used a combination of cloud and fog technologies for less energy consumption and less time delay. For more security, the software was used not to spend more time and energy and not leading to the patients' dissatisfaction in performing security operations with complex security methods. Besides, the highest level of data security can be achieved (1). This study's objective was to use the lightest measuring devices that do not interfere with the patient's daily activities without disconnection or damage in the devices (2). The devices' power source can hold energy for a long time, while it is not large and heavy. Hence, the devices are wireless with the most up-to-date technologies in their lightest and most flexible state (3-6)

Alert system, using a mobile phone has been considered to be the cheapest and easiest mode possible. Because any other system needs to use costly technologies that increase energy consumption during research and they also have time delays and will also create data security gaps.

Methods

Figure 1 presents the proposed system architecture. This system works as follows:

First, the sensors send the data to the mobile software via Low Energy Bluetooth (BLE). In the software, it is decided whether this data is high-risk or normal. If the data is high-risk, the data will be sent to the emergency medical center via SMS with a series of other information, including patient location, high-risk data, and time. The emergency team is then dispatched to the location, and the necessary measures are taken to improve the patient's condition. This information is then sent to the database along with the actions taken by the emergency team.

However, if the data is detected as normal by the software, the data will be sent to the patient database via the Internet at a certain time, e.g., at the end of the day.

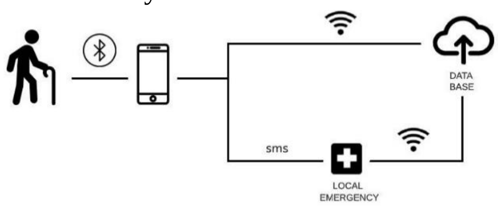

Figure 1. Proposed system architecture

The architecture of the application

The emergency warning page in the application includes user ID, date and time of measurement, patient location, sensitive data that triggered the alert, type of patient activity (for example, sitting), device charge level, device connection, and informing a patient friend or family about the emergency. In this situation, the patient's companion confirms whether he/she is going to the place or not. After the emergency team operates on the patient, the emergency team performs the medical operations on the patient and confirms the report so that the information can be sent to the patient's electronic medical record.

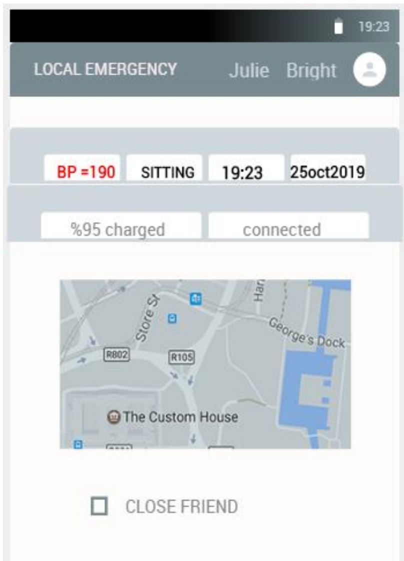

Figure 2. Patient monitoring program alert page

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The patient's daily observation page consists of daily patient observation, which means that biomedical signs have been measured and there has been no problem receiving biomedical information or symptoms. Therefore, only the time, location, and measured values are reported on this page. In this case, the day information will be sent to the patient's electronic medical record at the end of the day at 00:00:00.

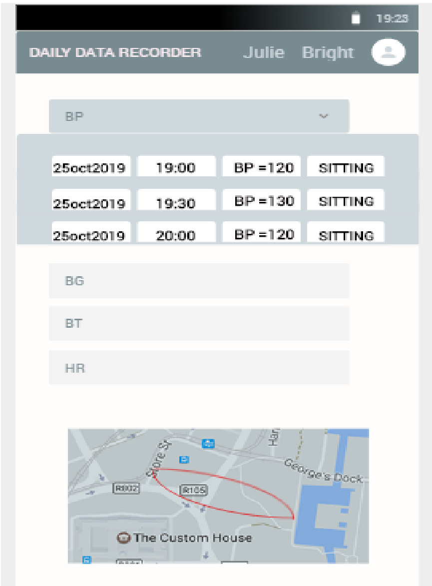


Figure 3. Patient monitoring page in the application

Database

After researching Big data and comparing other methods to our system (7), it was decided to use My SQL server linked to the software, which will send all information privately for each person to the person's database. With this method, we will no longer need to apply time-consuming and costly security measures, and we can ensure system security simply and safely.

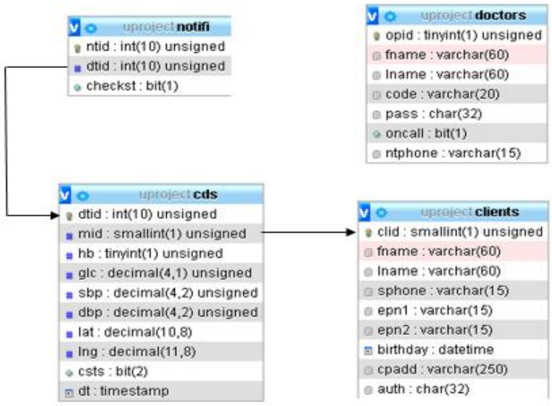
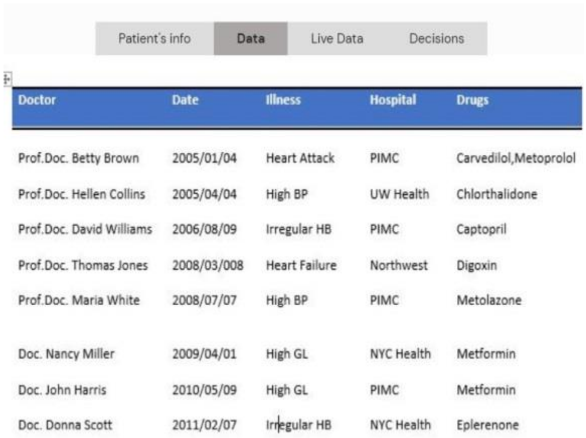


Figure 4. Database in the patient monitor application

The information will be displayed in the database, as shown in Figure 5. The doctor's name, date, type of disease, hospital, and medications prescribed to the patient in an emergency will all be recorded on the table. Also, in Figure 6, the patient's daily data and the sensors taken during the day are sent to the database and placed in the live data section.



Doctor	Date	Illness	Hospital	Drugs
Prof.Doc. Betty Brown	2005/01/04	Heart Attack	PIMC	Carvedilol,Metoprolol
Prof.Doc. Hellen Collins	2005/04/04	High BP	UW Health	Chlorthalidone
Prof.Doc. David Williams	2006/08/09	Irregular HB	PIMC	Captopril
Prof.Doc. Thomas Jones	2008/03/008	Heart Failure	Northwest	Digoxin
Prof.Doc. Maria White	2008/07/07	High BP	PIMC	Metolazone
Doc. Nancy Miller	2009/04/01	High GL	NYC Health	Metformin
Doc. John Harris	2010/05/09	High GL	PIMC	Metformin
Doc. Donna Scott	2011/02/07	Irregular HB	NYC Health	Eplerenone

Figure 5. Database and patient emergency data

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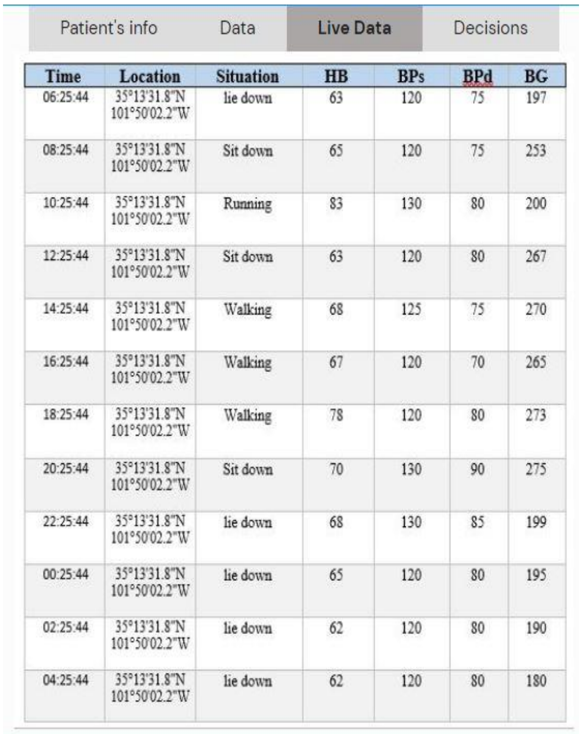

Time	Location	Situation	HB	BPs	BPd	BG
06:25:44	35°13'31.8"N 101°50'02.2"W	lie down	63	120	75	197
08:25:44	35°13'31.8"N 101°50'02.2"W	Sit down	65	120	75	253
10:25:44	35°13'31.8"N 101°50'02.2"W	Running	83	130	80	200
12:25:44	35°13'31.8"N 101°50'02.2"W	Sit down	63	120	80	267
14:25:44	35°13'31.8"N 101°50'02.2"W	Walking	68	125	75	270
16:25:44	35°13'31.8"N 101°50'02.2"W	Walking	67	120	70	265
18:25:44	35°13'31.8"N 101°50'02.2"W	Walking	78	120	80	273
20:25:44	35°13'31.8"N 101°50'02.2"W	Sit down	70	130	90	275
22:25:44	35°13'31.8"N 101°50'02.2"W	lie down	68	130	85	199
00:25:44	35°13'31.8"N 101°50'02.2"W	lie down	65	120	80	195
02:25:44	35°13'31.8"N 101°50'02.2"W	lie down	62	120	80	190
04:25:44	35°13'31.8"N 101°50'02.2"W	lie down	62	120	80	180

Figure 6. Data measured by sensors daily

These data allow the doctor to make decisions based on available data and the number of emergencies to prescribe medication and its health status. Besides, the doctor can consult with his/her other colleagues from other departments and use their experiences in different fields to reach the patient's best decision.

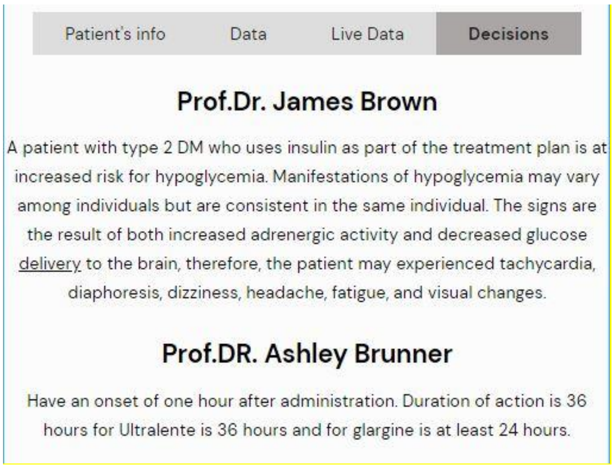

Figure 7. Section of decision-making based on data in which doctors in different departments can use each other's experiences and make the best decision

Alert system

The system immediately notifies the information center as soon as it detects any errors. This error could be a technical fault or connection of the device, the need to replace or charge the battery of sensors or data on the alert threshold.

If the data received from the sensors decreases or exceeds these values, the alert system will be activated and notify the emergency team.

We used a mobile gyroscope to diagnose the patient's condition to obtain more accurate data and make better decisions.

Table 1. The range of data received indicates the patient's health

Data type	Acceptable		Warning		Severe		Critical	
	Min	Max	Min	Max	Min	Max	Min	Max
BP	91	169	90	170	80	185	65	220
HR	51	139	50	140	40	180	32	210
BT	34.1	37.9	34	38	32	40	30	42
BG	90	120	85	160	80	199	75	300

Cloud and fog calculations

In this paper, based on other research in this field and studying reliable sources, (8) it was decided to use cloud and fog technology.

It is assumed that the project is in two parts. The first part is the fast data transmission section to the nearest emergency center, and the second part is the storage of large data in the patient database. For the first part, we considered fog technology because speed and security were very important, and we did not need heavy calculations because of the small amount of data. However, since bulk data is needed in the second part of the project and relatively stronger processing is required than in Part 1, cloud technology was used.

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Results

This project requires advanced sensors to perform their actions optimally, including the patient's comfort in using them, not limiting their daily actions (9,10), and the minimum-error method to achieve the desired result. Therefore, with extensive research on more than 450 articles in this field, two sensors were selected.

Laser-based quantum implantation for continuous glucose monitoring

This sensor is injected subcutaneously into the patient's adipose tissue. Therefore, blood sugar testing devices, which are generally reported to be invasive due to the invasive nature of several infections (11-13) and also, the inconvenience of the method for children or even forgetting or not having the competition to measure blood sugar daily made us choose this method.

Response time in this method is less than 5 minutes, which is a short time compared to other samples that reported up to 15 minutes (14).

The power supply in this device is through induction.

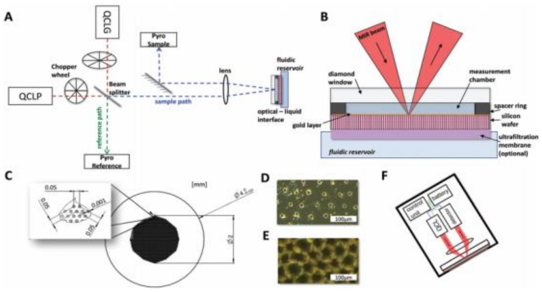

Figure 8. Experimental performance

A: Laser beams emitting from QCL-G and QCL-P are split into two beam paths by a beam slit. The reference path is used to record the laser power. Moreover, The sample path is used to obtain reflection signals from the measurement cell. Wheels have modulated both QCL outputs. B: Infrared liquid interface design made in two layers parallel to a thin opening spacer ring between them. The top window is a transparent MIR diamond window with an anti-reflective coating, and the lower part includes a gold-plated silicon wafer. A layer between two windows can be filled with a liquid, for example, water. The wafer's small holes ensure fluid flow from the fluidic reservoir outside the sensor to the water layer. An additional (optional) supernatant membrane can be attached to prevent water from entering certain molecules under the silicon wafer. At an angle of 8 degrees relative to the vertical line, the laser beam focuses on the gold film on the silicon wafer. The beam is guided through the liquid, reflected and passed through the liquid again, before being detected and aggregated by a pyroelectric wave detector (as shown in A). C: Detailed image of a gold-coated silicon wafer used for fluid exchange and as a MIR reflector at the same time. D and E show microscopic images of the top and bottom of the wafer, respectively. F: QCL-based implant with all required reservoirs (QCL, control unit, power supply, tracker, optics, optical interface).

Blood pressure measurement

To measure blood pressure, after reviewing articles and research in this field (15-18) and examining the strengths and weaknesses of each, it was decided to choose a sample that has almost no disturbance to the patient, without any problem in the results by shaking the patient, non-allergenic and antiperspirant and also with up-to-date technology. Therefore, we used the following technology.

With the least error among other similar devices and, least harmfulness to the body with low energy consumption, the above two sensors had a suitable design that would have almost no restrictions for the patient in performing daily activities (19).

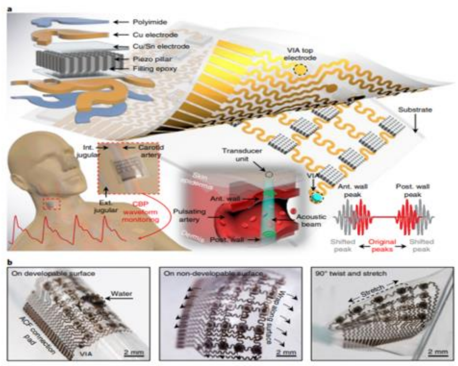

Figure 9. Design and mechanism of the tensile ultrasound machine

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At a high pulse repetition frequency (2000 Hz), the time of flight (TOF) signals of the pulsating anterior and posterior walls can be accurately recorded by an oscilloscope with a sampling frequency of 2GHz, which appears in the domain mode as separate peaks and displacements (Figure ۹-a., bottom right). This device can dynamically record pulsating blood vessels' diameter with a high spatial resolution (axial resolution of 0.77μm) and temporal resolution (500μs). The whole device is encapsulated by a silicone elastomer parallel to the human skin. The elastomer is only 15μm thick so that it can exchange sufficient mechanical strength and sound propagation performance. The hydrophobic nature of silicone elastomer creates a moisture barrier, protecting the device from possible corrosion of the body sweat (Figure ۹-b.). Considering the device's soft mechanics, the ultrasound patch is transformed to both expandable (Figure ۹-b, left) and non-expandable levels (Figure ۹-b, middle). This device is also sturdy and can withstand twisting and tension (Figure ۹-b., straight).

Discussion

In this study, up-to-date and low-error methods and tools were used. In general, various publications, books, and conferences have been used to collect over 500 up-to-date articles in this field to use the experiences of other people and use the weakness of other researches to provide a system with the least error rate.

By dividing the project into sections 1 and 2 and using cloud and fog technology simultaneously, we could engineer time, which was one of the essential factors in this project, sending error messages in the shortest possible time.

In this system, by considering the database connected to the software, we could prevent hacker attacks to a large extent. Besides, it was found that the more we want to increase security, in proportion to that cost, the time of data transfer increases and, the project loses its user-friendliness. It will also be difficult for children, the disabled, or the elderly to use the system.

Introducing digital medical records for each person is another achievement of this project. In this system, specialists can decide how to take medicine, type of medicine, and even other medical decisions in a safe environment, with biomedical and important patient information. With the introduction of this system, other problems such as drug interactions, spending a lot of time and money to refer to different specialists will be reduced.

According to the studies, the current project was compared with some projects in this field, and the result can be observed in Table 2.

Table 2. A simple comparison between our system and other related works

	IoT system	Monitoring capability	Detection capability	Prediction system	Low energy system	Real-time system
Rosli(4)	-	-	+	-	-	+
Wolgast(5)	+	+	+	-	+	+
Dewan(20)	-	-	-	+	-	-
Koshti(21)	+	+	-	-	-	+
Medhekar(22)	-	-	-	+	-	-
Jumbhulkar(6)	+	+	+	+	-	+
Raihan(23)	-	-	-	+	-	-
Our system	+	+	+	+	+	+

Research limitations

Limitations we encountered during the project are as follows:

- Increased energy storage capacity of devices
- Adding a process to diagnose the patients' eating habits to achieve accurate blood sugar rates
- Performing actions to save the patient's life during the waiting period until the emergency team has access to the person

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Recommendations for future work

Expanding this system to measure other biomedical parameters such as respiration rate and blood oxygen, as well as adding the ability to deliver the appropriate dose of medication to prevent an attack on the patient while waiting for the medical team to arrive, as well as a drug monitoring system are some of the suggestions, which are considered as important items during the investigations.

Conclusion

The proposed system provides facilities so that the person can be under the 24-hour supervision of a doctor without hospitalization and can easily carry out daily activities in their living environment. The patient can even travel without worrying about being away from the medical system. Doctors can also save time, prioritize patients, take the necessary measures based on the evidence in the patient's digital medical record concerning medications or diseases and emergencies that have occurred to the patient, and even consult with other specialists about the patients' favorable results.

Acknowledgement

I would like to express my special thanks of gratitude to my teachers (Dr.Hojatollah Hamidi) who gave me the opportunity to do this project and (Dr.Ali Broumandnia) which also helped me a lot in finalizing this project.

Ethical considerations:

The present article has been collected from reliable sources and up-to-date books and articles, then the strengths and weaknesses of each have been examined. The sources that we have used for writing this article, have been noted in the resources section. This article has been extracted from the dissertation with the code 208960123247 Azad university e-campus.

Author contribution

H.H. and A.B. were involved in planning and supervising the work. F.A. and H.H processed the data, performed the analysis, drafted the manuscript, and designed the figures. All authors aided in interpreting the results, working on the manuscript, discussing the results, and commenting on the manuscript.

Conflict of interest

Authors have no conflict of interest and take complete responsibility for the integrity and accuracy of the data. .

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