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DEVELOPMENT AND DEPLOYMENT OF A REAL TIME EMERGENCY PATIENT MONITORING SYSTEM

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Abstract:

This research deals with the design and implementation of a smart emergency patient monitoring system using wireless sensing and communication technologies. A wearable device was developed that monitors basic vital signs such as heart rate, temperature, and blood oxygen saturation, and displays the readings in real time on a digital screen. The system is based on a technical architecture that includes microcontrollers and wireless communication modules, enabling continuous monitoring without the need for direct human intervention. The results showed accuracy and stability of the measurements, enhancing the system's efficiency in clinical and field environments. The project represents a practical example of the use of IoT technologies in the health sector, and highlights the possibilities of developing medical infrastructure by integrating smart electronic systems that contribute to improving the quality of medical care and the speed of response to emergencies.

Keywords: Real-Time Monitoring, Emergency Healthcare System, Internet of Things (IoT), Wireless Sensor Networks, Vital Signs Monitoring

1. Introduction

With the continuous advancement in technology and communications, the healthcare sector has undergone a profound transformation in how medical care is delivered, diseases are diagnosed, and patients are monitored. This progress has led to the emergence of intelligent systems that significantly enhance the quality of medical services, particularly in emergencies that demand rapid response. The development of patient monitoring systems has become a crucial innovation, playing a fundamental role in improving treatment outcomes and reducing risks associated with delayed medical intervention

[1] [2].

Traditional patient monitoring methods present several challenges, including the constant need for medical staff to be physically present, the difficulty of continuously tracking vital signs, and the potential for human errors. As hospitals and healthcare centers face an increasing number of patients, the need for more efficient systems capable of providing real-time data has become evident. These advancements enable doctors and nurses to make timely and well- informed decisions, ultimately improving patient survival rates [1] [2].

Scientific research has demonstrated that modern technological innovations, such as remote patient monitoring systems, significantly enhance hospital efficiency and reduce mortality rates, particularly in emergency and intensive care units. These systems alleviate the burden on healthcare professionals by providing reliable and rapidly analyzable data, aiding in accurate diagnosis and timely medical intervention [1] [2].

Moreover, advancements in artificial intelligence and the Internet of Things have opened new possibilities for the development of intelligent systems capable of continuously monitoring patients without direct human supervision.

These technologies not only minimize potential human errors but also enhance patient experience and contribute to the overall improvement of healthcare services, as the demand for smart solutions in the medical field continues to rise; the development of cutting-edge patient monitoring devices has become imperative. This highlights the significance of researching and implementing advanced systems designed for emergency patient monitoring, with the goal of enhancing medical response speed and minimizing risks associated with critical conditions [1] [2].

Aim of the Project

This research aims to achieve several key objectives that contribute to the development and improvement of emergency healthcare through the design and implementation of an intelligent device for real-time monitoring of vital signs.

Problem Statement

In medical emergencies, delays in monitoring a patient's vital signs can lead to severe health complications or even death, especially in resource-limited environments or overcrowded healthcare facilities. Traditional monitoring devices are often stationary and require the patient to be in a hospital setting for continuous observation. Therefore, there is a critical need for a portable emergency patient monitoring system that can measure Electrocardiography (ECG), Blood Oxygen Saturation (SpO2), Blood Pressure, Body Temperature, and Heart Rate in real time. This device will wirelessly transmit data to healthcare professionals via a smart application or digital platform, enabling rapid medical intervention and timely decision-making.

By enhancing remote patient monitoring, this system aims to improve patient outcomes and reduce the risk of critical health deterioration.

Significance of project in Healthcare

The project represents a qualitative shift in the healthcare sector, enabling real-time and accurate monitoring of patients' vital signs, contributing to early detection of any changes in their health condition and enabling medical teams to respond quickly in emergencies. It also contributes to improving the quality of care by providing reliable data that helps doctors make informed treatment decisions, in addition to reducing the need for manual monitoring, which saves time and effort and enhances the efficiency of medical performance. The project is also a fundamental step towards developing a smart infrastructure in the healthcare sector, paving the way for the adoption of innovative solutions that contribute to raising the level of medical services provided and achieving more sustainable and effective healthcare [3].

Structure of the Project

a. Chapter One (Background, Aim of the Project, Problems Project, Significance of IoT in Healthcare, and Structure of the Project)

b. Chapter Two Literature Review (Literature Review)
c. Chapter Three Methodology (Components and Methodology)
d. Chapter Four Results (Results, Features Project, and Flaws Project)
e. Chapter Five Conclusion (Suggestions & Recommendations and Conclusion)

Literature Review

Previous studies

Several studies have focused on the design and implementation of emergency patient monitoring systems, aiming to enhance healthcare delivery through continuous monitoring and real-time data analysis. Notable among these are:

In a study conducted by Dr. Ahmed Ali and his team, titled "Remote Monitoring System for Critical Cases," a system based on Internet of Things (IoT) technologies was developed to monitor patients in intensive care units. The system collects real-time vital data, which aids in early detection of health deterioration and prompt medical intervention [4].

Dr. Laila Mohamed conducted a study as part of the "Smart Healthcare in Emergency" project. An integrated system combining sensors and modern communications was designed to provide real-time monitoring of critical cases, improving response times and reducing health risks [5].

A research team from Cairo University, led by Dr. Sami Mahmoud, conducted a study titled "Applications of the Internet of Things in Hospitals," where a system based on wireless networks was designed to collect and analyze vital data, contributing to improved medical procedures and reducing waiting times in emergencies [6].

In the "Smart Monitoring System in Emergency" project, led by Dr. Karim Youssef and his team, an interactive platform was developed that combines artificial intelligence and IoT technologies to analyze real-time data, enabling early detection of critical cases and prompt treatment decisions [7].

Mona Saeed's study, part of the "Improving Emergency Patient Care" project, focused on using digital analytics techniques to develop a monitoring system capable of alerting medical teams in a timely manner, contributing to improving the quality of care and reducing medical errors [8].

A team from Ain Shams University, led by Dr. Mazen Fathy, conducted a study titled "Design and Implementation of an Emergency Patient Monitoring System." The study developed a digital infrastructure that combines sensors and communications technologies to provide accurate data, contributing to rapid medical intervention and improving treatment performance [9].

A study titled "Developing an Intelligent Patient Monitoring System in Emergency Units," led by Dr. Naglaa Adel, explored the integration of Internet of Things technologies with intelligent algorithms to analyze biometric data, leading to reduced error rates and improved treatment outcomes in critical environments [10].

Hassan Ibrahim and his team presented a study titled "Real-Time Monitoring System for Emergency Patients," in which they developed a system based on wearable sensors connected to mobile phone applications, enhancing the accuracy of biometric measurements and contributing to the provision of continuous healthcare [11].

Sarah Khaled conducted a study titled "Application of Internet of Things Technologies in Emergency Healthcare." The study addressed the technical and security challenges in transmitting vital data and presented innovative solutions to ensure rapid and accurate monitoring in emergency settings [12].

A comprehensive study conducted by a research team from King Saud University, led by Dr. Fahad Al-Anzi, titled "Design and Implementation of an Advanced Emergency Monitoring System," developed a system that combines wireless technologies and smart sensors to provide real-time data, contributing to improved response speed and reduced medical risks in emergency situations [13].

Each of the above studies highlights the importance of using IoT technologies and smart systems to improve the quality and responsiveness of healthcare, confirming the feasibility of developing and implementing advanced patient monitoring systems in emergencies.

2. Materials and Methods

Components

Arduino Uno

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs - light on a sensor, a finger on a button, or a Twitter message - and turn it into an output - activating a motor, turning on an LED, publishing something online.

Figure 1. Arduino Uno.

Function:

Receiving vital data from sensors and analyzing it.
Sending signals to the OLED display or wireless communication systems.
Controlling the system's on and off according to the patient's health status

Specifications:

ATmega328P processor.
32 KB Flash Memory.

Equipped with digital and analog input and output interfaces to deal with different sensors.

MPS20N0040D

The MPS20N0040D is an electrical pressure sensor used to measure pressure in a variety of industrial and commercial applications. This sensor features high accuracy and the ability to measure low to medium pressures, making it ideal for use in process control systems and medical equipment. Its design incorporates advanced technologies that ensure stable performance and reliable measurements, making it a preferred choice in applications that require high accuracy and efficiency.

Figure 2. MPS20N0040D.

Function:

Measures blood pressure when combined with a suitable signal amplifier.

Specifications:

Pressure measurement range up to 40 kPa, provides an analog output that can be converted to a digital value via an ADC converter in the Arduino Uno.

MAX30100 Pulse Oximeter and Heart Rate Sensor

The Max30100 sensor is an effective and painless way to measure blood oxygen saturation and heart rate. It consists of two LEDs, one for red and one for infrared light, a photoreceptor, optical lenses, and an analog signal processor.

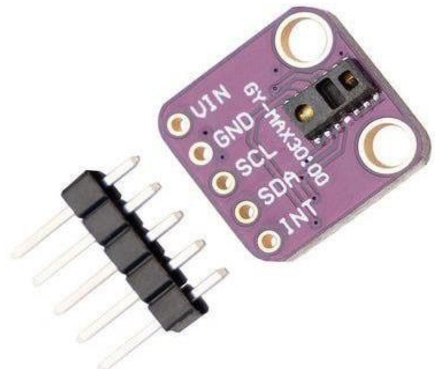

Figure 3. MAX30100.

Function:

Measures heart rate with the required accuracy.

Calculates blood oxygen saturation (SpO2), an important indicator of respiratory health.

Specifications:

It relies on red and infrared LEDs to measure changes in blood flow.

It operates at low current to reduce power consumption.

OLED display

The OLED display (short for organic light emitting diode) is available in 128 x 64 and is a simple raster graphics display. It has 128 columns and 64 rows, which makes a total of 128 x 64 = 8192 pixels. The display has only four pins and communicates with the Arduino using the I2C communication protocol.

Figure 4. OLED display.

Function:

Displays heart rate, oxygen level, and blood pressure.

Real-time data update capability

Specifications:

0.96 inch size or larger as needed.

Low power consumption with high contrast.

Lithium-Ion Battery (Li-ion Battery)

Lithium-ion is the most popular rechargeable battery chemistry used today. Lithium-ion batteries power the devices we use every day, like our mobile phones and electric vehicles. Lithium-ion batteries consist of single or multiple Lithium-ion cells, along with a protective circuit board.

Figure 5. Lithium-Ion Battery (Li-ion Battery).

Function:

Provides the power needed to operate the Arduino Uno and sensors.
Ensures the system continues to operate in the absence of an external power source.

Specifications:
Operating voltage: 3.7V – 7.4V depending on the required capacity.
High storage capacity with fast charging.

Jumper Wires

Wires are used to connect electronic components together and ensure data and power transfer between them.

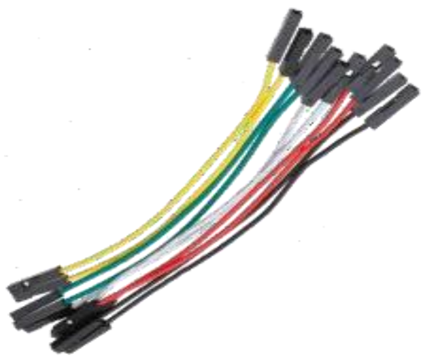

Figure 6. Jumper Wires.

Function:
Connecting sensors to the Arduino Uno.
Providing power between the battery and other components.

Specifications:

Wire Gauge: Typically 22 AWG to 30 AWG, making them suitable for simple electronic applications.

Connector Type: Comes with male-female or male-male connectors, making it easy to connect to circuit boards.
Length: Typically, lengths range from 5 cm to 30 cm, providing flexibility

DHT11

Temperature and humidity sensor an electronic sensor converts the moisture content in the soil into a measurable electrical signal. The sensor's output is a voltage signal ranging from 0 to 5 volts, indicating the moisture content in the soil. If the soil is dry, the output is 0 volts, and if the soil is very wet, it produces 5 volts.

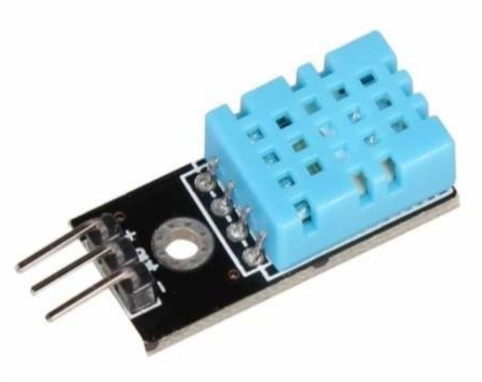

Figure 7. DHT11.

Function:
Measuring environmental temperature and humidity.
Providing accurate digital data to control units or processors.
Specifications:
Measurement Range: The DHT11 measures temperature from 0°C to 50°C and humidity from 20% to 80% RH with an accuracy of ±2°C and ±5% RH.
Operating Voltage: Operates from 3.5V to 5.5V DC, making it suitable for a variety of applications.
Data Interface: Provides digital output via a single-wire protocol, facilitating communication with microcontrollers.
TP4050 Lithium Battery Charger
The TP4050 charger is an integrated circuit designed to charge single-cell Lithium-ion and lithium-polymer batteries. It is easy to use and efficient in managing the charging process.

Figure 8. TP4050 Lithium Battery Charger.

Function:
Constant charging: Supplies the battery at a constant voltage (typically 4.2 volts) until it reaches full charge.
Constant current charging: Starts by supplying a constant current (CC) until the battery reaches the specified voltage.
Heat management: Includes a circuit to limit excessive heat during the charging process.
LED status indicators: Typically contain LED indicators to indicate the charging status (e.g., charged, full).
Specifications:
Charging voltage: 4.2V (suitable for lithium batteries).
Charging current: Adjustable, typically up to 1A.
Charging method: Constant current/variable current (CC/CV) charging.
Low current consumption: Ensures that the circuit does not consume significant power when in idle mode.
Overcharge protection: Requires additional protection circuits to protect against overcharging or deep discharge.

NodeMCU

The NodeMCU is a development board based on the ESP8266 chip and is commonly used in Internet of Things (IoT) projects. It combines the ability to connect to wireless networks with programming using Lua or Arduino.

Figure 9. NodeMCU.

Function:

Wireless connectivity: Easily connects to Wi-Fi networks.

Device control: Can be used to control electronic devices such as sensors and motors.

Flexible programming: Supports multiple programming environments such as Lua and the Arduino IDE.

Open source platform: Users can easily develop and share their projects.

Specifications:

Processor Chip: ESP8266.

RAM: 160 KB (varies by version).

Flash Memory: 4 MB (varies by version).

Number of Pins: Typically 11 GPIO pins.

Operating Voltage: 3.3 V.

USB Interface: For easy programming and power.

Rocker Switch

A rocker switch is an electrical switch used to turn electrical appliances on and off. Its design allows for switching between two states with a simple touch, making it easy to use.

Fast Charging Module Type-C PD65W

The Type-C PD 65W fast charging unit is a technology used to charge devices quickly and efficiently, providing up to 65W of power. It relies on the Power Delivery (PD) protocol to adjust the power level to the device's needs, reducing charging time.

Figure 10. Rocker Switch.

Figure 11. Fast Charging Module Type-C PD65W.

The system is based on an Arduino Uno microcontroller, which communicates with a MAX30100 sensor via an I2C interface (SDA and SCL) to measure heart rate and blood oxygen saturation using photo plethysmography. The MPS20N0040D pressure sensor is connected to one of the Arduino's analog pins to read pressure values after converting them to digital signals and calibrating them according to the sensor's own equations. The processed vital data is displayed in real time on two OLED displays, also connected via an I2C interface. One displays pulse rate and oxygen saturation, while the other displays pressure readings or any additional variables.

A Li-ion battery linked to a charging and protection module to ensure sustainability and electrical safety powers the project. All components are housed within a protective and organized box, with the MAX30100 pulse sensor mounted in a clip that can be placed on the patient's finger to accurately measure vital signs in emergencies.

Connection diagram

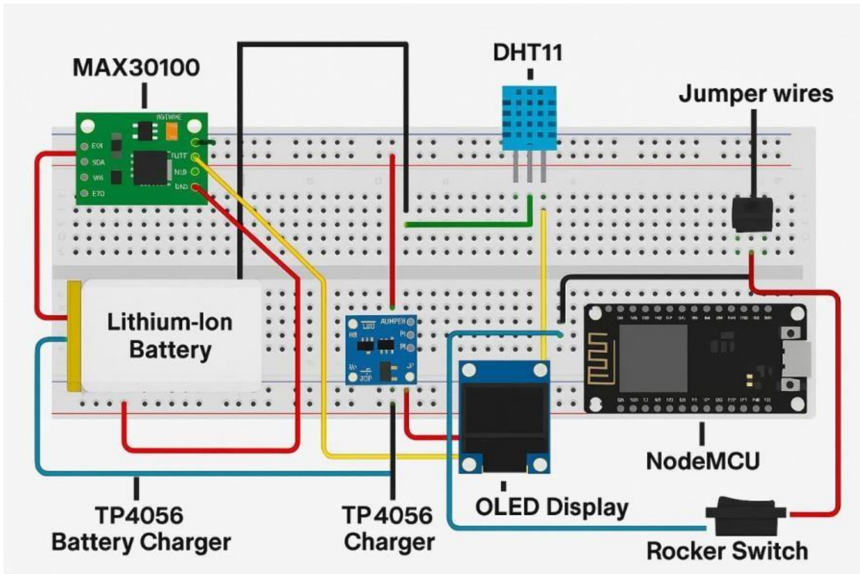

Figure 12. Connection diagram.

Project Design

The project includes a wearable device featuring OLED displays to show vital signs such as heart rate and temperature. The device is designed for ease of use in emergencies.

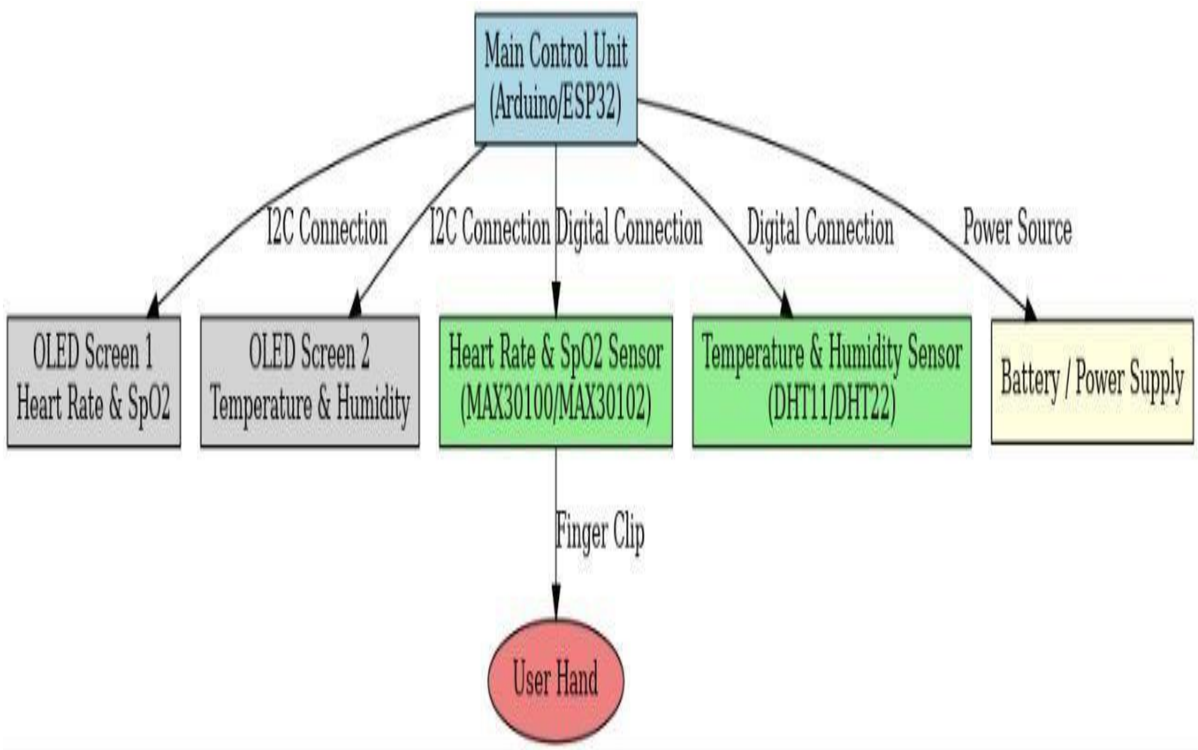

Figure 13. Device operating system.

3. Results and Discussion

In this research, an integrated system for monitoring vital signs was developed, utilizing a main control unit (Arduino/ESP32) that interacts with advanced sensors such as the MAX30100 for measuring heart rate and blood oxygen saturation (SpO2), and the DHT22 for assessing temperature and humidity.

Experimental results demonstrated notable stability in readings, with heart rates ranging from 60 to 100 beats per minute and SpO2 levels between 95% and 100%, while temperature values ranged from 20°C to 25°C and humidity levels between 40% and 60%.

This data was accurately and seamlessly displayed on OLED screens, enhancing user experience and facilitating easy access to health information. The system reflects a remarkable capability to provide real-time health insights, opening up vast prospects for future applications in personal healthcare.

Figure 14. Final form of the device (device operation).

Features Project

1. Continuous Monitoring: The device provides continuous vital sign monitoring for patients, helping to detect any changes in their health status early.
2. Immediate Alerts: It can send immediate alerts to doctors or family members when critical changes are detected, enhancing response times.
3. Ease of Use: Designed for ease of use in emergency situations, allowing medical staff to operate it without complications.
4. Improved Medical Decision-Making: Enhances the effectiveness of medical decision-making by providing accurate, real-time data.
5. Wide Applications: Applicable for patients with chronic conditions, in mobile healthcare settings, and as part of emergency response strategies.
6. Reduced Burden on Medical Staff: Decreases the need for continuous physical presence of medical staff, allowing them to focus on more critical cases.

Suggestions & Recommendations

1. Enhance Data Accuracy: It is recommended to develop advanced algorithms to improve the accuracy and reliability of measurements collected from sensors, ensuring health that is more precise monitoring.
2. Provide Continuous Training: Ongoing training programs for medical staff should be implemented to ensure effective utilization of the device and a thorough understanding of its features and functionalities.
3. Strengthen Security Measures: Strict security protocols should be adopted to protect patient data, including encryption and regular security updates, to mitigate risks associated with data breaches.
4. Expand Usage Scope: Expanding the application of the system to include small clinics and

healthcare centers is advised to enhance overall healthcare delivery and accessibility.

5. Conduct Performance Evaluations: Periodic evaluations of the system's performance should be conducted by gathering user feedback and analyzing outcomes to continuously improve service quality.
6. Collaborate with Stakeholders: Collaboration with health authorities and governmental bodies is encouraged to facilitate the adoption of the system and promote its implementation across hospitals and medical facilities.

4. Conclusion

Future work

a. Integrate with mobile applications (Android/iOS) to allow doctors and family members to monitor patient data and receive emergency alerts remotely.

b. Add cloud-based data storage to enable historical tracking and analysis of patient health data.

c. Implement artificial intelligence algorithms to analyze vital signs and predict potential critical conditions before they occur.

d. Expand to multi-patient monitoring, especially useful in emergency rooms or field hospitals.

e. Miniaturize the hardware design to create a more compact, wearable, and comfortable device.

f. Optimize power consumption by introducing fast-charging or solar- powered capabilities.

g. Include additional sensors such as ECG, GPS, and fall detection for elderly or at-risk patients.

h. Enhance cybersecurity measures by encrypting data and securing communications to protect patient privacy.

The "Design and Implementation of an Emergency Patient Monitoring System" project represents a significant advancement in the healthcare domain, exemplifying the integration of technology and medicine to enhance the quality of services provided.

By enabling continuous and accurate monitoring of vital signs, this system aims to improve the effectiveness of emergency responses and reduce health risks associated with delays in medical intervention.

The reliance on technologies such as the Internet of Things (IoT) and artificial intelligence (AI) in developing this system reflects contemporary trends in medical innovation, highlighting the necessity of adopting smart solutions to improve treatment outcomes.

However, challenges related to costs, data accuracy, and cybersecurity require careful consideration from policymakers and researchers in the field.

Thus, the implementation of the proposed suggestions and recommendations, such as enhancing measurement accuracy and providing ongoing training for medical staff, is crucial to ensure the maximum benefit from this system.

This project is not merely a new technology; it is a strategic step toward empowering healthcare institutions to address future challenges and improve the overall patient experience.

In conclusion, this project demonstrates how technological innovations can lead to tangible improvements in healthcare, opening new avenues for research and development in this vital field.

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