IoT-BASED ICU PATIENT HEALTH CARE MONITORING SYSTEM

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ABSTRACT

The healthcare sector has seen significant advancements with the integration of Internet of Things (IoT) technology, particularly in the critical care domain. This abstract presents the conceptualization and development of an IoT-based ICU Patient Health Care Monitoring System aimed at enhancing patient care and clinical decision-making processes. The system incorporates various IoT devices such as wearable sensors, smart monitoring equipment, and embedded systems to continuously collect patient health data in real-time.

The IoT-based ICU Patient Health Care Monitoring System operates by capturing vital physiological parameters including heart rate, blood pressure, respiratory rate, temperature, and oxygen saturation levels. These data are transmitted securely through wireless communication protocols to a centralized server for processing and analysis. Machine learning algorithms are employed to interpret the collected data, enabling early detection of anomalies or deterioration in the patient's health condition.

Furthermore, the system provides healthcare professionals with remote access to patient health data via a user-friendly interface, facilitating timely interventions and personalized patient care plans. Additionally, alerts and notifications are generated to notify healthcare providers of any critical deviations from the baseline parameters, ensuring prompt medical attention.

The implementation of the IoT-based ICU Patient Health Care Monitoring System offers several benefits, including improved patient outcomes, reduced healthcare costs, and enhanced operational efficiency within intensive care units. Moreover, the system promotes proactive healthcare management by enabling continuous monitoring and early intervention strategies.

In conclusion, the development of an IoT-based ICU Patient Health Care Monitoring System represents a significant advancement in critical care technology, revolutionizing the way patient health data is collected, analyzed, and utilized to optimize clinical decision-making processes and ultimately improve patient care outcomes.

KEYWORD: Wi-Fi module, Band Sensor, temperature Sensor, Physical Monitoring, flex Sensor

1. INTRODUCTION

The IoT-based ICU (Intensive Care Unit) patient healthcare monitoring system is an advanced network of interconnected devices and sensors designed to continuously monitor and manage patient health parameters in intensive care. This system uses Internet of Things (IoT) technology to collect, transmit and analyze real-time data. This provides healthcare professionals with timely insights and enables proactive actions when needed.

Here is an overview of the components and functions typically found in such a system

Sensors and Equipment Various sensors are used to monitor patients' vital signs and other health indicators. These sensors can include EKG sensors, pulse oximeters, blood pressure monitors, temperature sensors, respiratory rates and more. In addition, devices such as infusion pumps, ventilators and heart monitors can be integrated into the system.Data acquisition and transmission Data is collected from sensors in real time and wirelessly sent to a central monitoring device or cloud-based platform. Wireless communication protocols such as Wi-Fi, Bluetooth, Zigbee or cellular networks are usually used ford atatransmission.

Data processing and analysis Collected data is processed and analyzed using advanced algorithms and machine learning techniques. This analysis can identify abnormalities, trends and patterns in patient health parameters, facilitating early detection of worsening conditions or critical events.

Dashboard and Alerts Healthcare professionals have access to a user-friendly dashboard that displays real-time patiedata, trends and alerts. Alarms are triggered when certain predefined thresholds are exceeded or abnormalities are detected, prompting medical personnel to intervene in time.

Remote Monitoring and Telemedicine IoT-enabled monitoring systems allow healthcare providers to monitor patients' health remotely from anywhere there is an internet connection. This feature is particularly valuable for monitoring patients in remote locations or emergency situations, enabling timely interventions and reducing the need for constant bedside visits.

Integration with Electronic Health Records (EHR) Integration with existing hospital information systems and electronic health records allows seamless sharing of patient data between the monitoring system and other health IT systems. This integration ensures continuity of care and allows healthcare providers to access comprehensive patient information from one centralized location.

Security and Compliance Given the sensitivity of patient health information, effective security measures including data encryption, access control and compliance with health regulations such as the Health Insurance Portability and Accountability Act (HIPAA) are essential to protect patients. privacy and data integrity

2. LITERATURE SURVEY

A literature survey of IoT-based ICU patient monitoring systems would include a review of existing research, publications and academic publications related to this topic. Here is an overview of important topics and areas you may want to explore.

2.1 Technology Considerations:

- View research on various IoT technologies, sensors and communication protocols used in ICU patient monitoring systems.
- Explore research on wearable sensors, implantable devices and other emerging technologies for healthcare. monitoring.

2.2 Data Analytics and Machine Learning:

- Explore research on data processing, analysis and machine learning techniques applied to health data generated by the Internet of Things.
- Explore research on anomaly detection, predictive analytics and decision making. doing . support systems for early detection of debilitating diseases in patients.

2.3 Clinical Applications and Use Cases:

- View case studies and clinical trials evaluating the effectiveness of IoT-based critical care patient monitoring systems in real healthcare settings.
- Research specific diseases or patient populations. where IoT monitoring systems have shown promising results.

2.4 Security and Privacy:

- Explore security issues and privacy considerations related to IoT-based healthcare systems.
- Review research on encryption techniques, access control methods, and secure data transfer protocols to protect patient data.

2.5 User Experience and Human Factors:

- Explore user interface design, usability, and human-computer interaction in IoT-based health monitoring systems.
- Review studies on health care provider evaluation and patient satisfaction with monitoring solutions enabled through IoT.

By referencing a comprehensive literature review in these areas, you will gain valuable insight into the current state of the art. of critical care. state of the art, challenges and opportunities in IoT-based ICU patient monitoring systems.

3. METHODOLOGY

The methodology for developing an IoT-based ICU patient health care monitoring system typically involves several key steps:

3.1 *Needs Assessment*:

Begin by understanding the specific requirements and challenges of ICU patient monitoring. This involves consultation with healthcare professionals, including physicians, nurses, and other stakeholders, to identify critical parameters for monitoring and desired features of the system.

3.2 Sensor Selection and Placement*:*

Choose appropriate sensors capable of measuring vital signs and other relevant health parameters. Sensors may include those for monitoring heart rate, blood pressure, oxygen saturation, respiratory rate, temperature, and more. Determine the optimal placement of sensors on or around the patient's body to ensure accurate and reliable data collection.

3.3 Hardware Development:

Develop or procure the necessary hardware components for the IoT system, including sensors, microcontrollers, communication modules (such as Wi-Fi or Bluetooth), and power sources. Design the hardware infrastructure to be robust, energy-efficient, and capable of operating in the ICU environment.

3.4 Software Development:

Create the software infrastructure for data acquisition, transmission, storage, and analysis. Develop firmware for sensor integration, data processing algorithms, and communication protocols. Implement a user interface for healthcare professionals to access real-time patient data, set alerts, and visualize trends.

3.5 Integration with IoT Platform:

Integrate the hardware and software components with an IoT platform for centralized management and data analytics. Choose a suitable IoT platform that supports scalability, security, and interoperability with other healthcare IT systems. Ensure compliance with relevant standards and regulations governing healthcare data management.

3.6 Data Security and Privacy:

Implement robust security measures to protect patient data from unauthorized access, interception, or tampering. Encrypt data transmission between IoT devices and cloud servers, authenticate users, and enforce access controls based on role-based permissions. Adhere to regulatory requirements such as HIPAA to safeguard patient privacy.

3.7 Testing and Validation:

Conduct thorough testing of the IoT system in simulated and real-world ICU environments to ensure functionality, reliability, and accuracy of patient monitoring. Validate the system against predefined performance metrics and clinical standards. Solicit feedback from healthcare professionals to identify areas for improvement.

By following a systematic methodology encompassing these steps, developers can design and implement an effective IoT-based ICU patient health care monitoring system that enhances clinical care, improves patient outcomes, and optimizes healthcare delivery.

4 APPLICATION

The application of IoT-based ICU patient health care monitoring systems is multifaceted and encompasses various aspects of patient care, clinical management, and healthcare delivery. Here are some key applications:

4.1 Continuous Vital Sign Monitoring:

IoT devices equipped with sensors monitor vital signs such as heart rate, blood pressure, oxygen saturation, respiratory rate, and temperature continuously in real-time. This enables healthcare providers to track patients' physiological status continuously, detect early signs of deterioration, and intervene promptly to prevent adverse even**ts.**

4.2 Early Warning Systems:

IoT-based monitoring systems can be configured to trigger alerts and notifications when predefined thresholds or abnormal patterns are detected in patient vital signs. Early warning systems help healthcare providers identify patients at risk of deterioration, prioritize interventions, and prevent adverse outcomes such as cardiac arrests or sepsis.

4.3 Remote Monitoring and Telemedicine:

IoT technology enables remote monitoring of ICU patients' health status from anywhere with internet access. Healthcare providers can access real-time patient data, conduct virtual consultations, and adjust treatment plans remotely, enhancing access to specialized care and reducing the need for in-person visits.

4.4 Medication Management:

IoT-based monitoring systems can facilitate medication management by tracking medication administration, dosage, and adherence in real-time. Integration with electronic health records (EHR) and medication administration systems helps ensure accurate medication reconciliation, reduce medication errors, and improve patient safety.

4.5 Clinical Decision Support:

IoT systems analyze large volumes of patient data to provide clinical decision support to healthcare providers. Algorithms and predictive models identify trends, patterns, and potential risks in patient data, helping clinicians make evidence-based treatment decisions, optimize care plans, and personalize interventions based on individual patient needs.

4.6 Patient Surveillance and Safety:

IoT devices equipped with cameras, motion sensors, and location tracking capabilities enable continuous surveillance of ICU patients and their environment. Healthcare providers can monitor patient movements, detect falls or emergencies, and ensure compliance with infection control protocols, enhancing patient safety and reducing the risk of adverse events.

4.7 Rehabilitation and Remote Monitoring:

IoT devices support remote monitoring of patients undergoing rehabilitation or post-ICU care at home. Wearable sensors track patients' physical activity, mobility, and progress in real-time, allowing healthcare providers to remotely monitor recovery, provide guidance, and intervene as needed, promoting continuity of care and improving patient outcomes.

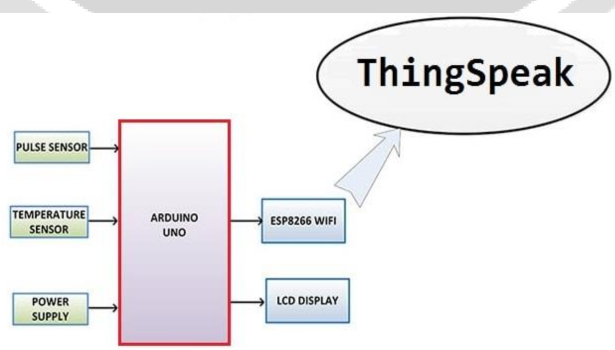

Fig.1 : Block Diagram

5 COMPOMENT USES

5.1 FLEX SENSOR:

A flex sensor is a type of sensor that changes its resistance when bent. It consists of a flexible substrate (usually made of plastic or other flexible materials) with conductive material (such as carbon or metal) printed or deposited on it. When the sensor is bent, the distance between the conductive materials changes, altering the resistance of the sensor. This change in resistance can be measured and used to detect the degree of bending or flexing.In an IoT-based ICU patient health care monitoring system, flex sensors can be utilized in various ways.

- Respiratory Monitoring:

Flex sensors can be integrated into wearable devices or patches placed on the patient's chest or abdomen to monitor respiratory movements. As the patient breathes, the chest or abdomen expands and contracts, causing the flex sensor to bend accordingly. The change in resistance of the flex sensor can be correlated with the respiratory rate and pattern, providing valuable information about the patient's breathing status.

- Movement and Activity Monitoring:

Flex sensors can be incorporated into wearable devices or smart textiles worn by ICU patients to monitor their movements and activity levels. By detecting changes in the degree of bending or flexing of the sensors, healthcare providers can assess the patient's mobility, physical activity, and adherence to rehabilitation protocols. This information can inform care plans and interventions aimed at promoting mobility and preventing complications such as muscle weakness and contractures.

- Position Monitoring:

Flex sensors can be attached to medical devices, such as bed rails or patient positioning aids, to monitor the patient's posture and position. By detecting changes in the angle or curvature of the sensors, healthcare providers can track the patient's position in bed, identify instances of immobility or prolonged positioning, and implement preventive measures to reduce the risk of pressure ulcers, musculoskeletal injuries, and other complications associated with immobility.

- Prosthetics and Orthotics:

Flex sensors are commonly used in the design and development of prosthetic limbs and orthotic devices to detect the movement and flexion of joints. In the ICU setting, flex sensors can be integrated into assistive devices or rehabilitation equipment used by patients with mobility impairments or orthopedic conditions. By monitoring the range of motion and muscle activity, healthcare providers can assess the effectiveness of rehabilitation interventions and adjust treatment plans accordingly.

5.2 NODE MCU

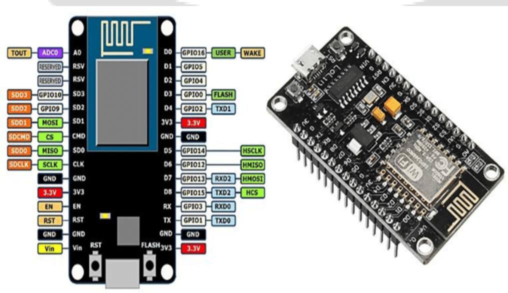

Fig.2 Node MCU

The NodeMCU is an open-source development board based on the ESP8266 Wi-Fi module. It combines the capabilities of a microcontroller unit (MCU) with built-in Wi-Fi connectivity, making it ideal for IoT (Internet of Things) applications. The NodeMCU development board features a Lua-based firmware and a USB-to-serial interface, simplifying the process of programming and interfacing with external sensors and devices.In an IoT-based ICU patient health care monitoring system, the NodeMCU can be used for various purposes:

- Data Acquisition*:*

NodeMCU boards can interface with sensors and collect data from various physiological parameters such as temperature, humidity, heart rate, blood pressure, oxygen saturation, and respiratory rate. The collected data can be transmitted wirelessly to a central server or cloud platform for real-time monitoring and analysis.

- Wireless Communication:

NodeMCU boards are equipped with Wi-Fi capabilities, allowing them to connect to local Wi-Fi networks and communicate with other devices or servers over the internet. This enables seamless integration of the monitoring system with existing hospital networks or cloud-based platforms for data storage and visualization.

- Data Processing and Analysis:

NodeMCU boards can perform basic data processing and analysis tasks locally, such as filtering, averaging, and threshold detection. This onboard processing capability reduces the need for constant communication with external servers and helps conserve bandwidth and power consumption.

- Alerting and Notification:

NodeMCU boards can be programmed to trigger alerts and notifications based on predefined criteria or thresholds. For example, if abnormal vital signs are detected, the NodeMCU can send alerts to healthcare providers via email, SMS, or push notifications, prompting timely intervention.

- Device Control and Actuation:

In addition to monitoring patient parameters, NodeMCU boards can also control external devices or actuators based on specific conditions or commands. For example, they can activate alarms, adjust environmental parameters (such as room temperature or lighting), or remotely control medical equipment in response to patient needs.

- Integration with IoT Platforms:

NodeMCU boards can interface with cloud-based IoT platforms or middleware solutions for data aggregation, storage, and analysis. By leveraging these platforms, healthcare providers can access centralized dashboards, visualize patient data in real-time, and generate reports for trend analysis and decision-making. Overall, the NodeMCU offers a versatile and cost-effective platform for developing IoT-based ICU patient health care monitoring systems. Its combination of microcontroller capabilities, built-in Wi-Fi connectivity, and ease of programming make it well-suited for collecting, processing, and transmitting patient data in real-time, enabling proactive and personalized patient care.

5.3 SALINE LEVEL SENSOR

A saline level sensor is a type of sensor designed to measure the level or volume of saline solution (saltwater solution) in a container or reservoir. These sensors typically utilize various technologies, such as capacitive, ultrasonic, or optical, to detect the presence and quantity of saline solution accurately.In an IoT-based ICU patient health care monitoring system, a saline level sensor can be employed for several purposes:

- *Infusion Pump Monitoring:*

Saline level sensors can be integrated into infusion pumps to monitor the remaining volume of saline solution in the IV (intravenous) fluid bag or reservoir. By continuously monitoring the saline level, healthcare providers can ensure that the infusion pump remains adequately supplied with fluid, preventing interruptions in medication delivery and optimizing patient care.

- Medication Management:

Saline level sensors can assist in medication management by monitoring the usage and availability of saline solution for intravenous administration. Healthcare providers can track the consumption of saline solution over time, detect deviations from prescribed infusion rates, and replenish supplies as needed to maintain uninterrupted therapy for ICU patients.

- Fluid Balance Monitoring:

Monitoring saline solution levels in IV fluid bags can provide valuable insights into patients' fluid balance and hydration status. By tracking the input and output of fluids, including saline solution, healthcare providers can assess patients' fluid requirements, monitor for fluid overload or dehydration, and adjust fluid therapy accordingly to maintain optimal physiological balance.

- Alerting and Notification:

Saline level sensors can trigger alerts and notifications when predefined thresholds or critical levels of saline solution are reached. Healthcare providers can receive alerts via email, SMS, or push notifications, prompting timely intervention to refill IV fluid bags, adjust infusion rates, or troubleshoot equipment issues, thereby ensuring uninterrupted patient care in the ICU.

Overall, saline level sensors play a vital role in optimizing medication management, fluid balance monitoring, and infusion therapy in ICU patient health care monitoring systems. By providing real-time visibility into saline solution levels and infusion pump status, these sensors contribute to safer, more efficient, and more reliable delivery of critical care to ICU patients.

5.4 Tempature Sensor (W1209)

The W1209 is a specific model of temperature sensor and controller module that is commonly used in various electronic projects. It is typically based on the DS18B20 digital temperature sensor and features a microcontroller unit (MCU) along with a relay output for controlling devices based on temperature readings.

In an IoT-based ICU patient health care monitoring system, the W1209 temperature sensor can serve several purposes:

- Environmental Monitoring:

The W1209 can be used to monitor the ambient temperature in the ICU environment. Maintaining a stable and comfortable temperature is essential for patient comfort and recovery, as well as for the proper functioning of medical equipment. The temperature readings from the W1209 sensor can be transmitted to a central monitoring system for real-time tracking and analysis.

- Patient Temperature Monitoring:

In addition to environmental temperature monitoring, the W1209 can also be employed to measure the body temperature of ICU patients. Elevated body temperature (fever) is a common indicator of infection or physiological stress and may require immediate attention from healthcare providers. By integrating temperature sensors such as the W1209 into wearable devices or patient monitors, healthcare teams can continuously monitor patients' temperature and respond promptly to abnormal readings.

- Thermostat Control:

The W1209 features a relay output that can be used to control heating or cooling devices based on temperature setpoints. In the ICU setting, this functionality can be utilized to regulate the temperature of patient rooms or equipment, ensuring optimal conditions for patient care. For example, the W1209 can be programmed to activate heating or cooling systems to maintain a specific temperature range within incubators, warming beds, or therapeutic devices.

- Data Logging and Analysis:

Temperature data collected by the W1209 sensor module can be logged and analyzed over time to identify trends, patterns, and anomalies. By monitoring temperature fluctuations, healthcare providers can assess the effectiveness of temperature control measures, track changes in patient condition, and identify potential risk factors for adverse events. This data can inform clinical decision-making and quality improvement efforts within the ICU.

Overall, the W1209 temperature sensor module offers a versatile and cost-effective solution for temperature monitoring and control in an IoT-based ICU patient health care monitoring system. Its compact size, digital output, and relay functionality make it well-suited for integration into wearable devices, medical equipment, and environmental monitoring systems, contributing to enhanced patient safety, comfort, and clinical outcomes.

6 ADVANTAGES

The advantages of an IoT-based ICU patient health care monitoring system are numerous and can significantly improve patient care, streamline clinical workflows, and enhance overall healthcare delivery. Here are some key advantages:

- Real-Time Monitoring:

IoT-based systems enable continuous real-time monitoring of vital signs and other health parameters, providing healthcare providers with immediate access to critical patient data. This allows for early detection of deteriorating health conditions and prompt intervention, potentially preventing adverse events.

- Remote Monitoring:

Healthcare professionals can remotely monitor ICU patients' health status from anywhere with internet access, enabling timely interventions and reducing the need for constant bedside observation. Remote monitoring also facilitates telemedicine consultations and improves access to specialized care, particularly in rural or underserved areas.

- Improved Clinical Decision-Making:

By aggregating and analyzing large volumes of patient data in real-time, IoT-based systems support evidence-based clinical decision-making. Healthcare providers can identify trends, patterns, and anomalies in patient data, leading to more informed treatment decisions and personalized care plans.

- Early Warning Systems:

IoT-based monitoring systems can be configured to trigger alerts and notifications when predefined thresholds or abnormal patterns are detected in patient vital signs. These early warning systems help healthcare providers intervene proactively, potentially preventing adverse events such as cardiac arrests or sepsis.

- Enhanced Patient Safety:

Continuous monitoring of ICU patients using IoT devices enhances patient safety by minimizing the risk of undetected complications or medical errors. Healthcare providers can closely monitor changes in vital signs, medication responses, and treatment effectiveness, ensuring timely adjustments to optimize patient outcomes.

- Efficient Resource Utilization:

IoT-based monitoring systems optimize resource utilization in the ICU by reducing the need for manual data collection and increasing the efficiency of healthcare workflows. Nurses and clinicians can focus their time and attention on high-priority tasks, leading to improved staff productivity and patient throughput.

7 DISADVANTAGES

While IoT-based ICU patient health care monitoring systems offer numerous advantages, they also present several potential disadvantages and challenges:

- Complexity and Technical Challenges*:*

Implementing and managing IoT systems in the ICU requires expertise in hardware, software, networking, and cybersecurity. Integrating diverse devices, sensors, and communication protocols can be complex and may require specialized skills. Technical issues such as device interoperability, connectivity issues, and data synchronization can also arise.

- Data Security and Privacy Concerns:

IoT devices collect and transmit sensitive patient health data, raising concerns about data security and privacy. Unauthorized access, data breaches, and cyberattacks pose significant risks to patient confidentiality and may result in legal and regulatory consequences. Ensuring robust security measures and compliance with healthcare regulations such as HIPAA is essential but challenging.

- Reliability and Accuracy:

The reliability and accuracy of IoT-based monitoring systems depend on the quality and performance of the sensors, devices, and communication networks involved. Malfunctions, sensor errors, signal interference, and data inaccuracies can occur, leading to false alarms, missed events, or incorrect clinical decisions. Regular maintenance, calibration, and quality assurance are necessary to mitigate these risks.

- Cost and Resource Constraints:

The initial investment and ongoing costs associated with deploying and maintaining IoT-based monitoring systems can be significant. Expenses may include hardware procurement, software development, infrastructure upgrades, training, and ongoing support. Healthcare organizations with limited budgets or resources may face challenges in implementing and sustaining IoT initiatives, potentially limiting access to advanced monitoring technologies.

- User Acceptance and Training:

Healthcare professionals and staff may require training and support to effectively use IoT-based monitoring systems. Resistance to change, workflow disruptions, and usability issues may arise during system implementation, affecting user acceptance and adoption. Comprehensive training programs and user-friendly interfaces are essential to overcome these barriers and ensure the successful integration of IoT technologies into clinical practice.

Overall, while IoT-based ICU patient health care monitoring systems offer significant benefits, addressing the associated disadvantages and challenges is crucial to ensure their successful implementation, adoption, and long-term sustainability in clinical practice.

8 FUTURE SCOPE

The future scope for IoT-based ICU patient health care monitoring systems is vast and holds tremendous potential for transforming critical care delivery. Here are some key areas of future development and advancement:

- **Advanced Sensor Technologies:**

Continued advancements in sensor technologies will enable the development of more accurate, reliable, and non-invasive sensors for monitoring a wider range of physiological parameters. Emerging sensor modalities, such as wearable biosensors, flexible electronics, and implantable devices, will enable continuous monitoring of vital signs, biomarkers, and disease-specific indicators with unprecedented precision and sensitivity.

- **Integration of Artificial Intelligence (AI) and Machine Learning:**

AI and machine learning algorithms will play an increasingly important role in IoT-based ICU patient health care monitoring systems. These algorithms can analyze large volumes of patient data to identify patterns, trends, and predictive markers associated with disease progression, treatment response, and clinical outcomes. AI-driven decision support systems will assist healthcare providers in making personalized treatment decisions, optimizing care plans, and predicting patient deterioration before it occurs.

- **Predictive Analytics and Early Warning Systems**:

IoT-based monitoring systems will evolve to include predictive analytics and early warning systems that can anticipate and prevent adverse events in real-time. By combining physiological data with contextual information, patient history, and environmental factors, these systems can identify patients at risk of deterioration and proactively intervene to mitigate potential complications, such as sepsis, cardiac arrest, or respiratory failure.

Overall, the future of IoT-based ICU patient health care monitoring systems is promising, with innovations in sensor technologies, AI-driven analytics, remote monitoring, and personalized medicine poised to revolutionize critical care delivery, improve patient outcomes, and enhance the overall quality and efficiency of healthcare delivery.

9 CONCLUSION

In conclusion, IoT-based ICU patient health care monitoring systems represent a transformative paradigm in critical care delivery, offering real-time monitoring, proactive intervention, and personalized patient care. By leveraging sensor technologies, wireless connectivity, and advanced analytics, these systems enable continuous monitoring of vital signs, early detection of deterioration, and optimization of treatment strategies. The integration of artificial intelligence, telemedicine, and wearable devices further enhances the scope and effectiveness of ICU patient monitoring, extending critical care expertise beyond traditional hospital settings and empowering patients to actively participate in their care. Despite the challenges posed by data security, interoperability, and ethical considerations, the future of IoT-based ICU patient health care monitoring systems holds immense promise for improving clinical outcomes, enhancing patient safety, and revolutionizing the delivery of critical care services. As these technologies continue to evolve, it is imperative to prioritize patient-centricity, equity, and ethical principles to ensure that IoT-based monitoring systems fulfill their potential as catalysts for transformative change in critical care practice.

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