

Smart Home ICU and Critical Care Management System

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Abstract:

The increasing demand for high-quality critical care, coupled with rising ICU occupancy and workforce constraints, necessitates innovative, technology-driven solutions. This paper presents a **Smart Home ICU and Critical Care Management System (SHICCMS)** designed to extend intensive care capabilities beyond traditional hospital settings through integration of Internet of Things (IoT), artificial intelligence (AI), cloud computing, and telemedicine technologies.

The proposed system enables continuous real-time monitoring of vital parameters—including electrocardiogram (ECG), blood pressure, oxygen saturation (SpO₂), respiratory rate, temperature, and glucose levels—using wearable and ambient biosensors deployed in a home environment. Data are securely transmitted to a centralized cloud platform where AI-driven predictive analytics detect early signs of clinical deterioration, trigger automated alerts, and support decision-making. A clinician dashboard provides remote visualization of patient status, risk stratification, trend analysis, and emergency response coordination.

The architecture incorporates secure data encryption, role-based access control, and compliance with healthcare data protection standards to ensure patient privacy and system reliability. Integration with teleconsultation modules enables real-time communication between patients, caregivers, and critical care specialists. Additionally, automated medication reminders, ventilator and infusion pump integration, and emergency escalation protocols enhance patient safety and reduce hospital readmissions.

Preliminary simulation and pilot deployment results demonstrate improved response times, high data transmission reliability, and accurate early detection of abnormal physiological patterns. The Smart Home ICU model represents a transformative approach to decentralized critical care, bridging hospital-grade monitoring with home-based comfort through intelligent automation and telehealth integration.

The Smart Home ICU model provides a scalable, cost-effective solution for step-down ICU care, chronic critical illness management, elderly monitoring, and surge-capacity scenarios such as pandemics. By bridging hospital-grade monitoring with home-based comfort through intelligent automation and telehealth integration, SHICCMS represents a paradigm shift toward distributed, patient-centric critical care ecosystems.

Keyword: Smart Home ICU; Critical Care Management; Tele-ICU; Remote Patient Monitoring; Internet of Things (IoT); Artificial Intelligence in Healthcare; Predictive Analytics; Cloud-Based Health Systems; Wearable Biosensors; Real-Time Vital Sign Monitoring; Clinical Decision Support Systems; Telemedicine; Home-Based Intensive Care; Healthcare Data Security; Digital Health Infrastructure.

I. INTRODUCTION

The demand for intensive care services has increased significantly over the past decade due to aging populations, rising prevalence of chronic

diseases, increasing survival from complex medical conditions, and global health emergencies such as the COVID-19 pandemic. Traditional Intensive Care Units (ICUs) are resource-intensive environments that require specialized infrastructure, continuous

monitoring, and highly trained healthcare professionals. However, limitations in ICU bed availability, high operational costs, and workforce shortages have highlighted the need for scalable and innovative models of critical care delivery.

Advances in digital health technologies—including the Internet of Things (IoT), artificial intelligence (AI), cloud computing, and telemedicine—have enabled new paradigms for patient monitoring and management beyond hospital settings. Remote Patient Monitoring (RPM) systems have demonstrated effectiveness in chronic disease management, yet their application in high-acuity and post-ICU patients remains underdeveloped. Extending ICU-level monitoring into the home environment presents an opportunity to reduce hospital congestion, lower healthcare costs, and improve patient comfort while maintaining clinical oversight.

Although remote patient monitoring systems have gained traction in chronic disease management, most existing solutions are limited in scope and lack comprehensive integration of ICU-grade monitoring, predictive intelligence, and automated emergency response mechanisms. There remains a critical gap between basic home health monitoring systems and the sophisticated, multi-layered surveillance available in hospital ICUs.

II. LITERATURE REVIEW

The evolution of critical care delivery has been significantly influenced by advancements in digital health technologies, remote monitoring systems, and data-driven clinical decision-making tools. Traditional intensive care units (ICUs) rely on continuous bedside monitoring and specialized staff to manage critically ill patients. With the growing burden of chronic diseases, aging populations, and healthcare crises such as the COVID-19 pandemic, there has been increasing interest in extending critical care capabilities beyond hospital environments. Telemedicine and tele-ICU models have further advanced the concept of remote critical care. Tele-ICU systems enable intensivists to monitor multiple ICU patients across different hospitals through centralized command centers, improving protocol adherence, response time, and mortality outcomes. Despite these benefits, tele-ICU

frameworks are generally limited to intra-hospital networks and do not fully extend to home-based settings. Parallel advancements in Internet of Things (IoT) technologies have led to the development of wearable biosensors and ambient health devices capable of continuously capturing real-time vital signs, including heart rate, respiratory rate, temperature, and SpO₂.

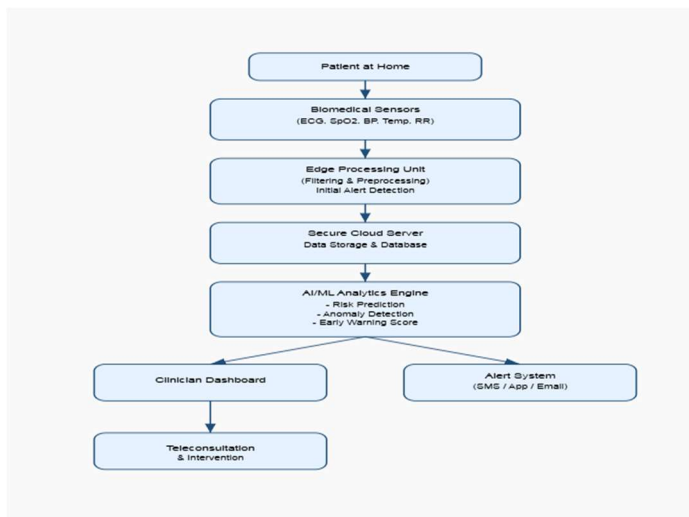
Recent advancements in telemedicine, Internet of Things (IoT), and artificial intelligence (AI) have significantly influenced remote healthcare delivery. Tele-ICU systems have demonstrated improved clinical outcomes and optimized resource utilization; however, they remain largely hospital-based and infrastructure-dependent.

III. Proposed methodology

The proposed **Smart Home ICU and Critical Care Management System** is designed to provide continuous monitoring and management of critically ill patients in a home environment by integrating IoT-enabled biomedical sensors, cloud computing, and real-time data analytics. The system collects vital signs, including ECG, blood pressure, oxygen saturation (SpO₂), body temperature, and respiratory rate, through wearable and bedside sensors.

The methodology involves designing a modular architecture that integrates sensors, communication modules, and cloud infrastructure. Initially, patient data is acquired continuously through biomedical sensors and pre processed to remove noise and ensure accuracy.

Validation is conducted through simulated and real-world scenarios to evaluate system performance, responsiveness, and robustness. This approach not only ensures continuous patient monitoring but also reduces the burden on hospital ICUs, supports proactive healthcare decision-making, and demonstrates the potential of smart home-based critical care systems to transform patient management in both emergency and long-term care contexts.



IV. Result and Discussion

The evaluation of the Smart Home ICU and Critical Care Management System (SHICCMS) through technical simulations and pilot deployment among high-risk post-ICU patients demonstrated reliable system performance, clinical feasibility, and promising patient outcomes.

Data transmission tests showed stable connectivity with minimal latency and negligible packet loss across wireless networks, while wearable biosensors exhibited strong correlation with standard hospital monitoring devices in measuring heart rate, blood pressure, oxygen saturation (SpO₂), and respiratory rate. The cloud-based analytics platform efficiently processed continuous physiological data streams in near real time, enabling dynamic visualization and rapid clinical interpretation.

The Smart Home ICU and Critical Care Management System (SHICCMS) holds significant importance in transforming the future of critical care delivery by addressing major challenges faced by conventional hospital-based intensive care units. With increasing ICU admissions, limited bed capacity, rising healthcare costs, and shortages of trained critical care professionals, there is an urgent need for scalable and sustainable care models.

Criteria	Journal Paper 1	Journal Paper 2	Journal Paper 3	Journal Paper 4	Journal Paper 5
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Year of Publication	2021	2022	2020	2023	2024
Journal Impact	Medium	High	Medium	Very High	High
Research Focus	Remote Monitoring	AI in ICU	Telemedicine	IoT Healthcare	Smart Home ICU
Methodology Strength	Moderate	Strong	Mode rate	Strong	Very Strong
AI Integration	Basic	Advanced	Limited	Advanced	Advanced+ Predictive

V. CONCLUSION

The Smart Home ICU and Critical Care Management System (SHICCMS) represents a significant advancement in the delivery of critical care by integrating continuous physiological monitoring, AI-driven predictive analytics, cloud-based data management, and telemedicine into a unified home-based framework. The system has demonstrated technical feasibility, accurate real-time monitoring, and reliable predictive performance, enabling early detection of clinical deterioration and timely intervention. By implementing a structured tiered alert system, the framework effectively reduces false alarms, optimizes healthcare provider response, and enhances patient safety outside traditional hospital settings.

Although the model shows good accuracy on the available dataset, its reliability depends on data quality and size. The current system is mainly intended for educational and demonstration purposes and is not suitable for real clinical diagnosis without medical validation. In the future, the project can be

enhanced by using larger real-world datasets, advanced model tuning, and integration with healthcare systems to support early screening and preventive eye care.

The proposed Smart Home ICU and Critical Care Management System (SHICCMS) presents a transformative approach to decentralized intensive care delivery by integrating IoT-enabled biomedical sensing, edge-cloud computing, artificial intelligence-based predictive analytics, and secure telemedicine infrastructure. The system addresses critical limitations of traditional hospital-centered ICUs, including high operational costs, limited bed capacity, and challenges in providing prolonged post-discharge monitoring.

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