

USE CASE

Avoiding ICU Admission in a Case of Septic Encephalopathy Through Enhanced Connected Care Monitoring

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DOI: <https://doi.org/10.30953/thmt.v9.507>

Keywords: biosensors; elderly; ICU; remote monitoring; septic encephalopathy

Abstract

Aim: This report presents the hospital stay of an elderly patient with septic encephalopathy who was admitted to the patient care unit. Through the use of enhanced remote care monitoring, admission to the intensive care unit (ICU) was avoided.

Case History: An 81-year-old gentleman with diabetes and hypertension presented to the Emergency Department complaining of generalized bilateral weakness of the upper and lower limbs and a recent history of acute gastroenteritis. The patient was evaluated and admitted to the non-ICU patient care unit for further management. On examination, he was hemodynamically stable but exhibited inattention and reduced wakefulness, which responded to verbal stimulation. Stool BioFire was positive for Shiga toxin-producing *E. coli*. The patient received a provisional diagnosis of septic encephalopathy.

Because of multiple issues, the patient was connected to Enhanced Care Monitoring (ECM) with ongoing surveillance by a nurse and physician from the Command Center. Three days after admission, the patient experienced respiratory desaturation with a n SpO₂ of 74%. The Command Center team immediately informed the nursing staff to take action. Within 2 h, a second critical alert was generated in response to tachycardia (HR 178/min). Once again, the nursing staff was informed promptly by the Command Center team. Bedside vitals confirmed tachycardia, the physician was notified, and with treatment, the patient's heart rate returned to normal, obviating the need to transfer the patient to the ICU. Throughout the rest of the hospitalization, the patient improved symptomatically in response to the management of sepsis and was discharged home.

Discussion: In this elderly patient with septic encephalopathy, enhanced remote wireless monitoring using wearable biosensors was used to track vital signs and identify deteriorating patterns at an early stage. The Command Center team was able to contact the nursing staff rapidly. In response, appropriate action was taken to avoid an ICU admission.

Conclusion: Wearable and implanted sensors can monitor elderly patients in the non-ICU patient care unit without hindering mobility. In this case, tachycardia was managed, and transfer to the ICU was not needed. These findings support the need for large-scale trials to confirm these observations.

Plain Language Summary

As individuals age, they undergo physiological changes that can result in a decline in health and an increased vulnerability to infections. Sepsis, a severe infection, poses a significant risk for the elderly and may lead to ICU admissions, with high mortality rates. This article presents a case study of an 81-year-old patient with diabetes, hypertension, and septic encephalopathy who was effectively managed in a non-ICU patient care unit without ICU admission.

To enhance monitoring, the patient was equipped with a wireless biosensor patch that continuously transmitted vital signs to a nursing station and a Command Center. Abnormalities triggered alerts, ensuring timely intervention. The patient's condition was remotely monitored for 3 days. During this time, decreased blood oxygenation levels and a rapid heart rate were promptly addressed, preventing ICU admission.

Wireless biosensors and continuous monitoring played a key role in preventing life-threatening incidents. This technology offers a noninvasive way to monitor patients, especially the elderly, reducing the burden on families and healthcare costs. This article emphasizes the potential of remote patient monitoring in non-ICU settings to enhance care, avoid unnecessary admissions, and decrease hospital stays. These findings support the need for large-scale trials to validate these findings further.

Submitted: March 12, 2024; Accepted: May 21, 2024, Published: June 30, 2024

Aging is associated with a progressive decline in physiological homeostasis, resulting in changes in organ functions, functional decline, multimorbidity, and frailty.^{1,2} As the immune system ages, its normal capacity to defend against infections, malignant cells, and autoreactive cells diminishes, leading to increased susceptibility to infection. Worldwide, sepsis is the leading cause of admissions to intensive care units (ICUs) and the most common cause of death in the ICU.³ According to the Sepsis-3 guidelines,⁴ sepsis is defined as life-threatening organ dysfunction caused by a dysregulated host response to infection.

Sepsis has a direct impact on the immune system due to adverse alterations of the production, maturation, function, and apoptosis of immune cells⁵—major contributing factors to poor outcomes in sepsis cases. Maddux and colleagues⁶ found a strong connection between disrupted innate immune responses and organ failure in people with sepsis. Malfunction of several organs leads to significant disruption of the immune response, potentially hastening the advancement of sepsis.

The brain is often the first organ to be impacted by inflammation, and because of this, neurological damage is frequently worsened by sepsis.⁷ Septic encephalopathy is a complex condition characterized by diffuse cerebral dysfunction triggered by the body's response to infection. It ranges from mild symptoms like inattention or disorientation to severe disturbances in consciousness, including coma. Patients presenting with septic encephalopathy exhibit evidence of severe systemic infection with sepsis or systemic inflammatory response syndrome.⁸

Septic patients with compromised hemodynamics are typically admitted to the ICU. However, not all patients with sepsis require ICU admission. Those who are sufficiently stable may be admitted to patient care units. Admitting elderly patients to the care units reduces the risk of nosocomial infections, as elderly patients are already susceptible to infection.⁹ However, these patients should be closely monitored.

The National Early Warning Score (NEWS) and Modified Early Warning Score (MEWS) are crucial for identifying early deterioration in patient care units.¹⁰ The NEWS2 system is recommended for acute hospitals and implemented in most settings. Despite their imperfect specificity for sepsis, NEWS and other screening tools play a

crucial role in promoting early recognition and prompt intervention for patients at risk of deterioration. They provide a standardized approach to risk assessment, facilitating timely escalation of care when necessary. Additionally, when used with clinical judgment and thorough evaluation, these tools can enhance patient safety and improve outcomes in non-ICU patient care unit settings.

Early warning scores are good predictors of unfavorable patient outcomes and could be used in select patients needing frequent monitoring—although there is no clear evidence to link them to monitoring frequency.¹¹ Based on a 7-point scale, patients with low NEWS are evaluated every 6 to 12 h, while those above six are followed hourly. Monitoring of each patient depends on the patient's clinical condition.¹²

It is a challenge for the staff working in the patient care unit where there might be one nurse for six patients to monitor a patient's vital signs at different times. Unfortunately, unanticipated clinical deterioration in these patients might go undetected if it occurs during the interval between routine vital sign measurements.¹³ This unexpected clinical deterioration can result in a prolonged hospital stay, admission to the ICU, higher mortality, and increased costs.

Remote patient monitoring can track vital signs, identify deteriorating patterns at an early stage, and alert the healthcare staff, thereby reducing ICU admissions.¹³ Here, a case of an elderly patient for whom ICU admission was avoided using wireless continuous monitoring is detailed.

Case Report

An 81-year-old man with diabetes and hypertension presented to the Emergency Department (ED) with generalized weakness in both upper and lower limbs following a recent history of acute gastroenteritis. There was no history of fever, cold, vomiting, paranesthesia, or trauma. On examination, the patient exhibited inattention and reduced wakefulness, which responded to verbal stimulation. The patient was hemodynamically stable.

The Sequential Organ Failure Assessment Score (SOFA) on admission was 2 (Glasgow Coma Scale [GCS] 13–14, creatinine 1.2–1.9 mg/dL). The SOFA score is a simple, objective tool that calculates organ dysfunction in six systems. It accurately predicts in-hospital mortality in patients with severe sepsis and hypoperfusion.¹⁴

The change in SOFA over 72 h positively correlates with in-hospital mortality. The SOFA score helps to gauge the progression of sepsis and guide decisions about providing care in the non-ICU patient care unit or the ICU. Upon admission, this patient's SOFA score was 2, prompting his transfer to the non-ICU patient care unit for sepsis treatment. Considering the patient's medical history, continuous monitoring was initiated to ensure diligent observation and management of their condition.

The patient was admitted to the non-ICU patient care unit for further management. He continued to be stable hemodynamically with mildly deranged renal function (creatinine 1.4 mg/dL). His GCS continued to be 13–15. A BioFire GI Panel (multiplexed nucleic acid test) was positive for Shiga toxin-producing *E. coli*. A provisional diagnosis of septic encephalopathy was made as the findings based on a CT scan were normal.

Following the sepsis pathway protocol, the patient received prompt fluid resuscitation, with cultures sent for analysis. Lactate levels were in the normal range. Additionally, broad-spectrum antibiotics were initiated within the first hour of presentation, in line with recommended practices for managing sepsis. The patient also had a decrease in urine output, and renal parameters were periodically reevaluated.

Lumbar cerebrospinal fluid (CSF) analysis revealed WBC: 6,000 μ L, RBC: 10 million/mcL, protein: 72 g/dL, and glucose: 98 mg/dL. GeneXpert MTB/RIF for tuberculosis was negative. Arterial blood gas analysis revealed mild metabolic acidosis with HCO_3^- : 21 mEq/L, pH: 7.302, pO_2 : 105, pCO_2 : 42 mmHg, and BE: 2. To rule out the cause of weakness, a nerve conduction study was done, which was normal. Accordingly, the patient was treated for septic encephalopathy. Additional laboratory results after admission are listed in Table 1.

In view of his elderly age and multiple comorbid conditions, the patient was connected to ECM. A wireless sensor/patch (Figure 1A) was connected to the patient's chest, which collected data on heart rate, respiratory rate,

and temperature. Saturation and blood pressure were collected from the companion device (Figure 1B).

Once the biosensor patch is applied, vitals are captured from the patient every minute and transmitted through a Wi-Fi signal to the nursing station dashboard and the command center dashboard. Abnormal vital signs are alerted in red, and the attending nurse immediately attends to the patient and resolves the alert.

Figure 2 shows an example of vital signs displayed on the dashboard. Only the SpO_2 is showing abnormality in this example—flashing in red as the value of SpO_2 is less than the threshold for the patient. Earlier a respiratory rate of 27 breaths per minute was noted, which might have been caused by the patient shifting in bed or consuming food. It is not flashing red to indicate an alarm because the staff acknowledged and addressed the positioning adjustments that caused it. Based on the patient's clinical circumstances, we set specific thresholds for the patient's vital signs. Thresholds help reduce the number of alarms that the team must respond to, as well as help bedside nurses experience less alarm fatigue. If the alert is not resolved at the nursing station level, the command center staff informs the attending nurse to resolve the alert while continuously monitoring the patient's vital signs.

The patient was constantly monitored by a nurse and doctor remotely from the command center. Three days after admission, desaturation with a low SpO_2 of 78% at 2:52 PM was noted. The nursing staff on the care unit was alerted by the command center team via phone. The nursing station alert turnaround time has been specified by us, with the command center staff stepping in to handle the alerts if the nursing station does not address them within 15 min. This has been added to the workflow and is progressively being lowered to improve the system's functionality.

Missing the alerts might occur when the nurse is with another patient. As a result, the system has a double check to notify the bedside staff nurse of the patient's essential information. In this case, in response to the alert, vital signs were checked at the bedside again. A decrease in oxygen saturation was observed, resulting in the initiation of oxygen therapy via nasal cannula at 2 L/min. The patient continued to rely on supplementary oxygen to sustain his O_2 saturation levels, indicating an unexpected deviation from the typical course for a patient presumed to be stable.

Two hours later, another critical alert (i.e. tachycardia at 178 bpm) occurred. The nursing staff was alerted once more, vital signs were rechecked at the bedside, and it was confirmed that the alert was triggered by the patient's positioning. The correction was made, and the physician was notified. Figure 3 displays the trends of heart rate and oxygen saturation on the ECC dashboard.

Table 1. Laboratory results after admission

Laboratory tests	Results
Creatinine	1.4 mg/dL
BUN	16 mg/dL
Sodium	140 mEq/L
Potassium	5.3 mEq/L
Total leucocyte count	9,900 cells/mm ³
Platelet count	2.32 lakhs/mm ³ *
C-reactive protein	29.4 mg/dL
Blood sugar	180 mg/dL
Hemoglobin A1c	6.4%

*A lakh is a unit in the Indian numbering system equal to one hundred thousand (10^5): 2.32 lakhs/mm³ = 232,000 cells/mm³.

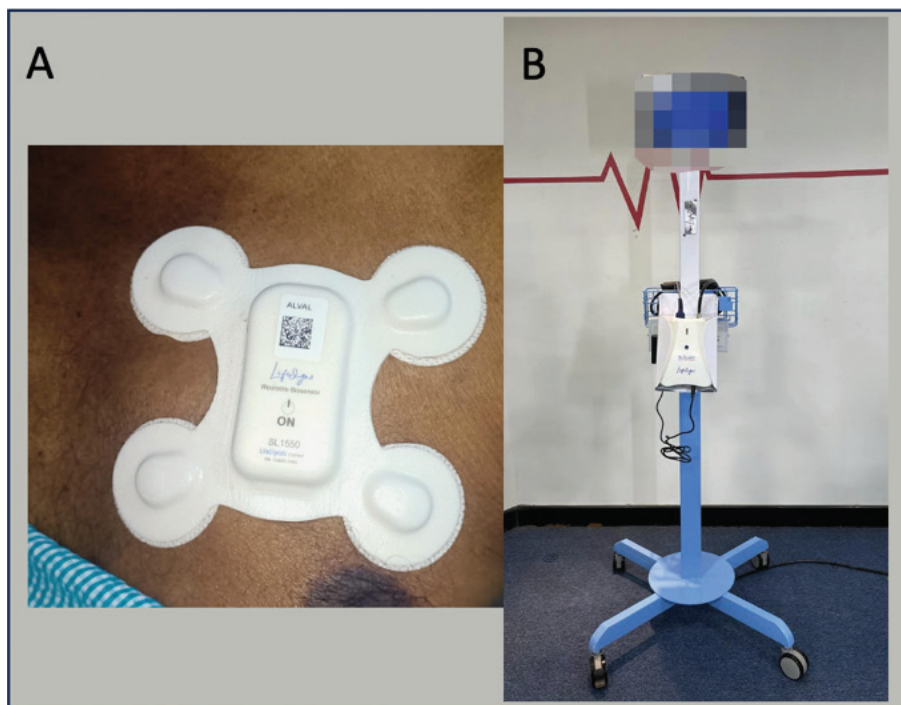


Fig. 1. The wearable biosensor patch (A) was attached to the patient’s chest and collected data on heart rate, respiratory rate, and temperature. The companion device (B) recorded blood pressure and oxygen saturation.



Fig. 2. An example of vital signs displayed on the nursing station dashboard and the command center dashboard. Note: only the SpO₂ is showing abnormality. In this example, flashing red is in response to a value of SpO₂ that is less than the threshold for this patient.

Heart rate data will be recorded every second and sent to the dashboard. The SpO₂ will be monitored every minute and sent to the dashboard. Any alteration in the vital signs can be readily detected. If the vital signs quickly return to normal, no intervention is necessary. If vital signs do not return to their baseline levels, interventions such as administering oxygen or evaluation by a cardiologist will be performed, as in this patient, after validating the vital signs at the bedside. Even a single aberrant vital sign can result in unexpected occurrences if not addressed promptly.

The 12-lead ECG showed sinus tachycardia. Reversible causes such as fever and pain were ruled out. The cardiologist’s order to initiate treatment with a beta blocker was carried out. Subsequently, the patient remained stable. By promptly administering appropriate sepsis treatment, which included fluids and broad-spectrum antibiotics, the patient’s symptoms improved, and weakness was relieved. The individual was conscious, alert, and stable regarding

blood circulation, and kidney function normalized. Blood culture results came back negative. After full recovery, the patient was discharged on the seventh day without the need for ICU admission.

Discussion

An elderly patient with altered sensorium diagnosed to have septic encephalopathy was successfully managed in the patient care unit, avoiding an ICU admission, and discharged 7 days later. Wireless biosensors were used to monitor the patient’s vital signs and alert the medical team as needed. Timely necessary action was taken that obviated a life-threatening incident.

Wireless sensor technologies have multiple applications in healthcare. Combining wireless sensors and network connections with computing and artificial intelligence has made it easier to monitor patients and avoid critical situations.¹³

An increasingly elderly population in developed countries is a major problem. According to the Population Reference Bureau,¹⁵ over the next two decades, the population aged 65 years and older in developed nations will increase to nearly 20% of the total population. Governments and health service providers need to provide quality care and cost-effective service to an elderly population. Wearable and implantable body sensor network systems that do not interfere with mobility enable patients to be monitored remotely. A review by Lin Sun et al.¹⁶ indicates that using multi-parameter continuous monitoring

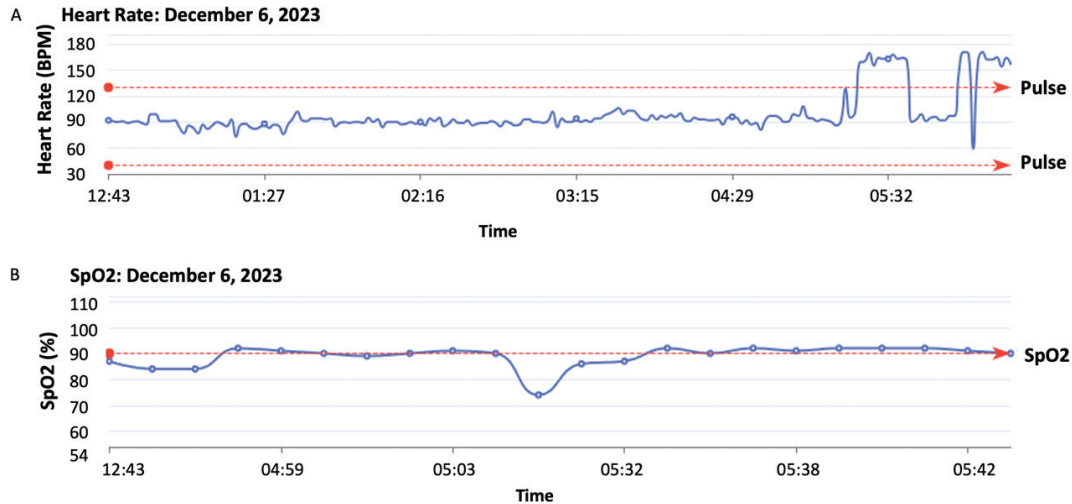


Fig. 3. Trends in heart rate (A) and oxygen saturation (SpO₂) (B) depicted on the Enhanced Care Monitoring dashboard.

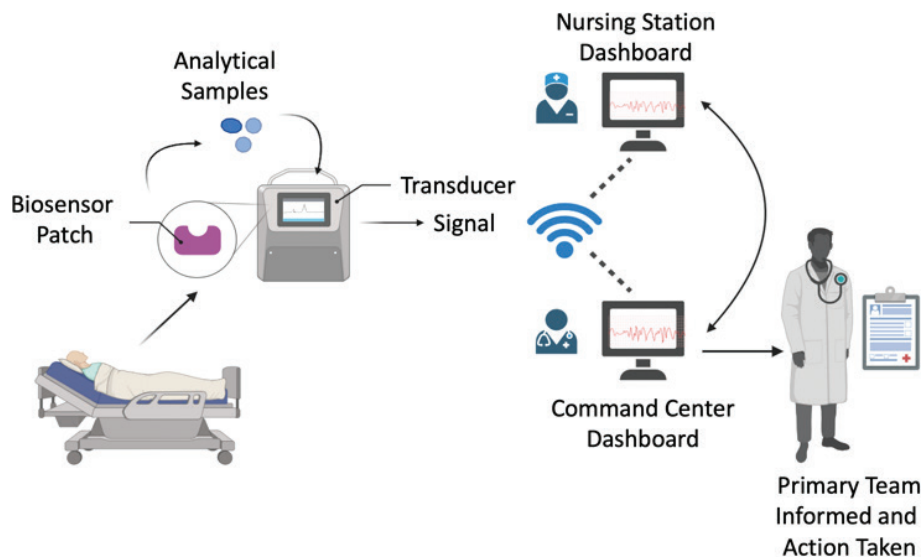


Fig. 4. Workflow and data flow of continuous patient monitoring. Created by Biorender, 2023.

outside the ICU provides clinical benefits. In high-risk patients, continuous monitoring reduces the duration of stay, the number of calls to be attended to by the rapid response team, and the mortality rate.¹⁶

Figure 4 illustrates the workflow and data flow of continuous patient monitoring. In the patient care units, the nursing staff usually monitors vital measurements manually. This is time consuming and labor intensive. With biosensors, vital signs can be continuously monitored without the need for direct bedside measurements. This potentially streamlines the process, reduces the need for manual measurements, and allows healthcare providers to access real-time data remotely. Printing essential chart data for documentation ensures that vital sign information is still recorded and accessible to healthcare professionals. However, it is essential to ensure that the wireless

monitoring system is reliable and accurate, as any glitches or failures in the system could lead to missed vital sign data. Overall, this transition represents a modernization of healthcare technology, potentially improving efficiency and enabling more comprehensive monitoring of a patient's vital signs.

In this case, the patient was connected to a wearable biosensor. The patch was attached to the patient's chest. Patient data were transmitted to the network, with vital data displayed on the dashboard screen at the nursing station and at the command center dashboard, where a doctor and a nurse continuously monitored the patient's vital signs. Vital signs that deviated from the predefined threshold triggered alarms at the nursing station dashboard and command center dashboard. This ensured that appropriate action was taken immediately.

Although this patient’s abnormalities did not require immediate ICU care, it is crucial to intervene promptly to prevent severe deterioration, especially since a heart rate of 170 bpm was abnormal. However, in this case, the patient quickly responded to initial stabilization and treatment. Therefore, it was decided to continue managing the patient in the non-ICU patient care unit rather than transferring to the ICU.

Remote, continuous monitoring of vital signs in patients cared for in the non-ICU patient care unit reveals robust data and offers several advantages over intermittent monitoring. A systematic review by Brekke et al.¹⁷ and Churpek et al.¹⁸ explored trends in intermittently monitored vital signs, revealing limited evidence but suggestive associations with clinical deterioration, with respiratory rate emerging as a key predictor. While continuous monitoring technology shows promise, evidence supporting its routine use in care units remains insufficient. Combining

electronic healthcare systems with trend analysis could enhance early detection of deterioration.

In this case, a patient’s admission to the ICU was not contingent on the presence of two abnormal values. Nonetheless, if the abnormality had not been detected and treated promptly, this patient would have been admitted to the ICU. In other words, early intervention based on abnormal values can potentially stabilize the patient’s condition, preventing the need for escalation to the ICU. This highlights the importance of proactive monitoring and intervention to prevent the worsening of a patient’s condition. Also, the burden on the family and healthcare costs can be partially mitigated by carefully monitoring patients on the ward, avoiding ICU admission.

Remote patient care monitoring has many potential challenges and limitations, which are highlighted in Figure 5.

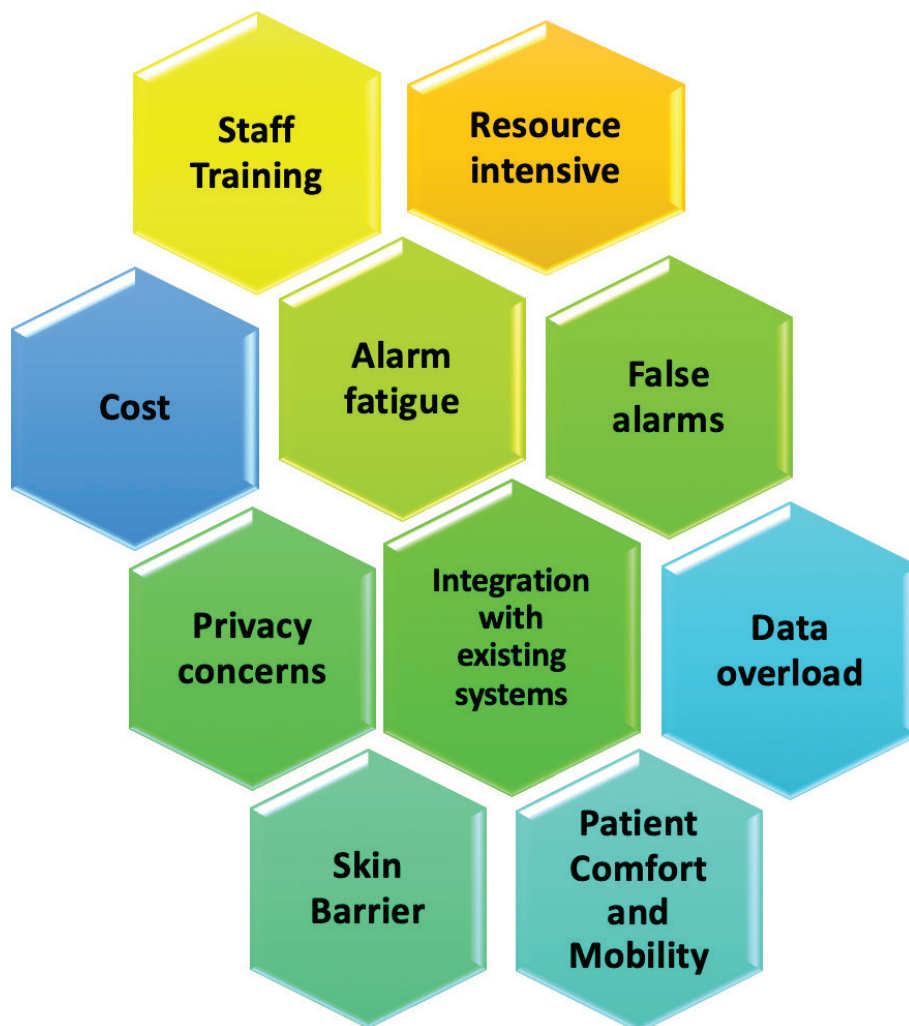


Fig. 5. Potential challenges and limitations for remote patient care monitoring.

Table 2. Contributions in this case study in support of further research

Contributions	Benefits
Pioneering Approach	Demonstrates innovative use of remote continuous patient monitoring technology to manage complex conditions such as septic encephalopathy.
Clinical Relevance	Highlights the potential benefits of remote continuous monitoring in improving outcomes for patients with critical illnesses.
Healthcare Challenges	Enables timely intervention and monitoring of patients, regardless of geographical location or healthcare resource availability.
Future Research and Practice	Provides insights for clinicians, researchers, and policymakers on the feasibility and effectiveness of remote continuous patient monitoring in Indian healthcare.

Practical Considerations

Nurses and staff commonly express concern that remote patient monitoring will increase their workload,^{12–15,17–19} whereas others believe it will reduce their workload and increase positive patient outcomes.²⁰ Lanssens et al.²¹ reported no increase in workload for healthcare practitioners using the technology. Other perceived risks include alarm fatigue, concerns about privacy and security, and cost-effectiveness.

Alarm Fatigue

Continuous monitoring systems often generate numerous alarms, which can result in crucial alarms being missed or ignored, compromising patient safety. In addition, constant monitoring might lead to false alarms, unnecessary diagnostic testing, and medical staff alarm fatigue.²² Many monitoring systems produce false alarms due to technical glitches or patient movement. Sorting these false alarms can waste healthcare provider time and decrease system reliability.

Privacy and Security

Remote monitoring of health data requires safeguarding patient privacy and autonomy, especially among elderly individuals vulnerable to exploitation. Obtaining informed consent is crucial and involves clearly explaining issues such as data usage, access, and control. However, challenges with integration persist due to legal constraints and privacy concerns among practitioners.

Security concerns arise from third-party data storage, while data accuracy issues stem from technology distrust and false positives.²³ That said, embracing remote monitoring offers significant benefits, including better outcomes, cost savings, and enhanced care quality. Addressing these hurdles is pivotal for realizing its full potential in healthcare systems.

Cost Effectiveness

Remote monitoring enables early detection of health issues, which can reduce costly hospitalizations and emergency visits while managing chronic conditions proactively to prevent complications. However, accessibility

issues persist for low-income patients due to financing challenges.²⁴ Despite concerns about costs, studies show remote monitoring can save money by tracking self-management supplies, reducing clinic visits, and supporting insurance reimbursement. Addressing financial barriers is crucial to harness the full potential of remote monitoring in optimizing healthcare spending and resource utilization.

During daily bedside rounds, physicians must examine data from continuous monitoring, which also aids in determining whether a patient can be discharged. In addition, vital signs are demonstrated to predict patient deterioration,¹⁴ and therefore, the availability of these continuous vital sign measurements will assist clinical decision-making regarding patient discharge. In our case, the patient was discharged directly from the non-ICU patient care unit in stable condition after 1 week.

Limitations

The lack of literature on prospective randomized controlled trials in remote patient monitoring in India is a significant issue. Further research is needed to evaluate the cost-effectiveness and sustainability of remote patient monitoring models, especially in resource-constrained settings. Comparing remote patient monitoring outcomes with traditional care can help identify areas for improvement. In addition, risk-stratification tools can enhance the effectiveness of remote patient monitoring, leading to better resource allocation and improved patient outcomes.

Conclusion

This case study is important for future research on the benefits of Enhanced Connected Care Monitoring (Table 2).

From the perspective of clinical practice, remote patient monitoring in non-ICU settings has the potential to mitigate the need for ICU admissions and reduce the risk of life-threatening incidents. Monitoring, as in this case, was particularly beneficial for an elderly patient at increased risk of admission to ICUs.

This report is the initial documentation of the successful treatment of an elderly patient with septic

encephalopathy in a non-ICU setting. The treatment was achieved by utilizing remote patient monitoring technology featuring wearable biosensors. This technology enables the delivery of a higher level of care in non-ICU patient care units, reducing unnecessary admissions to the ICU and minimizing the duration of hospital stays. Large-scale randomized controlled trials are necessary to confirm these findings.

Funding

None.

Financial and Non-Financial Relationships and Activities

No financial support was provided by an source. The authors declare no conflict of interest.

Contributors

In addition to writing the manuscript with critical revisions, Dr. Hima Bindu Kotamarthy made substantial contributions to the conception and design of this work and the acquisition, analysis, or interpretation of data. Dr. Sai Praveen Haranath contributed to the final approval of the version to be published. Drs. Sai Praveen Haranath and K. Subba Reddy were responsible for all aspects of the work, ensuring that questions related to the accuracy or integrity of any part of the work were appropriately investigated and resolved. All authors have approved the manuscript and agree with its submission to Telehealth and Medicine Today.

Data Availability Statement

For inquiries regarding data availability, contact the corresponding author.

Application of Ai-Generated Text or Related Technology

Quillbot was used to check for plagiarism percentage. For Figure 4, Generative AI images were created using BioRender software.

Acknowledgments

Thanks to Dr. Rahul Khandelwal for running the project. Mr. Pavan Thanneru, Mr. Bhaskar Reddy, and Mr. Jagadish Sidagam for their immense help in retrieving the data from the software.

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