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Tele-ICU and Critical Care Patient Nursing Care through Remote Monitoring: Review Study

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Abstract

Tele-Intensive Care Unit (Tele-ICU) systems use state-of-the-art telemedicine technologies to monitor and advise on critically ill patients in real time, filling intensivist gaps and enhancing nursing care in ICUs. The review study compiles current literature to assess the effects of Tele-ICU and nurse-led remote monitoring of nursing care of critically ill patients based on clinical outcomes, nurse workload, and implementation challenges. This study highlights how Tele-ICU programs allow for continuous monitoring, improve adherence to best practices, and decrease mortality and length of stay (LOS). The impact results in fewer patient safety events, decreased nurse burnout, and equity of service distribution, particularly in rural and underserved populations. Barriers to implementation include high costs, technical challenges, and staff acceptance. The review identifies the innovative role of the Tele-ICU nurse as a "second set of eyes" providing real-time support to bedside staff through interprofessional collaboration and responsiveness to real-time data. Future health care research must consider standardizing outcome measurement, address issues of cost-effectiveness, and strengthening staff education to maximize the value of Tele-ICU. The research presents a summary statement advocating for critical investment in technologies and education to leverage the full potential of critical care provision.

Keywords: Tele-ICU, remote monitoring, critical care nursing, patient outcomes, telemedicine

Introduction

The increasing acuity of patients in the intensive care unit (ICU) setting, combined with international shortages of intensivists and critical care nurse specialists, has increased the use of telemedicine technology in critical care facilities (Lilly et al, 2011). Tele-ICU, or electronic ICU (eICU) is a new mode of care that uses technologies to facilitate the monitoring and management of ICU patients by trained critical care teams remotely. The technologies are built on real-time audio/visual communication, electronic health records (EHRs), and high quality analytics to allow for efficient, seamless, real-time monitoring (Kleinpell et al, 2016). Tele-ICU's primary objective continues to be minimizing care provision gaps in the tail end of critical care expertise delivery, especially in rural hospitals and underserved populations, and improved bedside nurse

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support in the management of complex, high-acuity patients (Ofoma et al, 2021). Tele-ICU has transformed nursing practice in ICUs by providing real-time monitoring of patients, swift response to alerts about patient emergencies, and a vehicle for teamwork and interprofessional collaboration (Poncette et al., 2020). Despite the potential for a large impact, Tele-ICU implementation is limited due to high acquisition costs, technological constraints, and clinician buy-in (Kumar et al., 2013). This review presents a summary of how Tele-ICU and remote patient monitoring can support nursing practices in relation to critically ill patients, with categories of clinical outcomes, nurse workload, restraints, and generating areas of upcoming trends such as artificial intelligence (AI). Additionally, it proposes further research and bedside use to enhance the utility of Tele-ICU systems.

Tele-ICU

Tele-ICU refers to a high-tech telemedical system using the network of audiovisual technologies, data merging technologies, and computerized systems to enable remote groups of critical care teams to monitor and care for ICU patients virtually in real time (American Telemedicine Association, 2014). The team members and services are coordinated usually from a central command center manned by a multidisciplinary team of intensivists, advanced practice providers, critical care nurse specialists, and data analysts. They then use linked systems of EHRs, telemetry monitors, vital signs monitors, and imaging systems to review the entire range of patient data (Groves et al., 2008). The Tele-ICU system's foundation consists of the use of high-definition cameras, two-way audiovisual communication devices (both stationary and mobile), the decision support software, and risk stratification predictive algorithms (Buchman et al., 2018). The Philips eICU system is the most widely used platform in the US, supporting up to 11% of the ICU beds in non-federal facilities, regardless of its potential for far-reaching use (Lilly et al., 2014).

The variation of tele-ICUs may also lie in the level of activity. Some of the tele-ICUs provide around-the-clock full-time coverage, which allows continuous monitoring of the patient's clinical status throughout the day, while others simply provide scheduled teleconsults, usually after hours or for singular acute clinical events (Avdalovic & Marcin, 2019). The appropriateness of the models aligns with the degree that the individual hospital can customize tele-ICU services for their specific needs, such as supplementation for staffing shortages, or use in resource-limited environments of patient care. Even the utilization of the latest communications technology, such as real-time data analytics and machine learning algorithms, enables the tele-ICU teams to pick up on early signs of patient deterioration, thus enabling proactive intervention (Buchman et al., 2018).

Tele-ICU nurses are incorporated into the model of care and are considered the "second set of eyes" to assist bedside providers (Kleinpell et al., 2016). The tele-ICU nurse prospectively evaluates patient data such as vital signs, labs, and imaging studies, and can identify changes in patient status, usually regarding the timeline leading to an acute clinical crisis, such as early sepsis or acute respiratory failure. When a potential problem is identified initially by the tele-ICU nurse, the nursing role consults bedside clinician personnel to assist with accelerating intervention and often helps providers with interventions in life-threatening events (Rosenfeld et al., 2000). The collaborative care model serves to strike the balance of executing care through a combination of the technical skill of a remote specialist and the bedside skill of a field provider.

Numerous studies suggest that Tele-ICU systems can improve patients' compliance with evidence-based best practice protocols, for example, ventilator management, sepsis identification and management, and glycemic control (Lilly et al., 2011). These benefits translate to real-time clinical outcomes such as lower ICU mortality, shorter length of stay, and fewer preventable complications (Lilly et al., 2011). Successful use of the Tele-ICU, however, depends on a number of important factors: effective coordination of bedside staff and remote site personnel, standardized clinical protocol, and a comprehensive education program designed to keep all personnel up to date on the use of the telehealth technologies (Shahpori et al., 2011). Successful use also means considering barriers, including the interoperability of the installed EHRs of the hospitals and Tele-ICU systems, acceptance of the remote monitoring by healthcare providers, and getting to the future desired state of the healthcare organization. Figure 1 provides an overview of the Tele-ICU system infrastructure diagram.

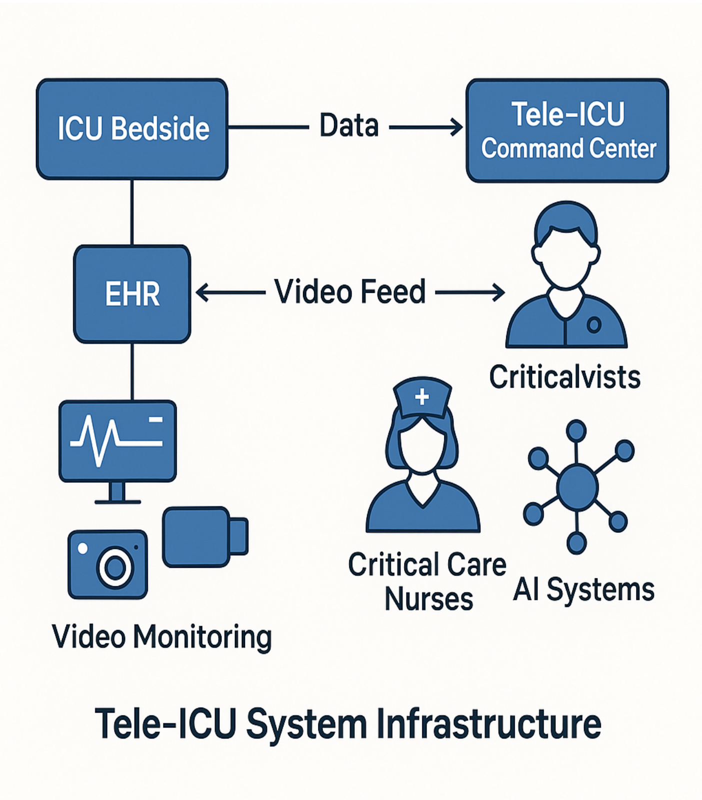

Figure 1: Tele-ICU System Infrastructure Diagram.

Impact on Nursing Practice

Improving Patient Safety and Outcomes

Tele-ICUs significantly improve patient safety through their capacity to monitor continuously and their ability to respond quickly to changes in the patient's condition (Thomas et al., 2009). Lilly et al. (2011) reported that there was a 26% decrease in hospital mortality and a 20% decrease in ICU length of stay when Tele-ICU intervention was made when compared to a control group in a multicenter study of 118,990 patients. Tele-ICU nurses can demonstrate vital signs patterns (e.g., early signs of sepsis or inadequate respiratory function) by observing more than one patient simultaneously and initiating interventions (Morrison et al., 2010). It can be especially useful in under-staffed ICUs, where the nurse-to-patient ratio is not optimal (Bauman & Hyzy, 2014). Tele ICU also provides reminders and decision support to follow the best practice, including the ABCDEF bundle of delirium prevention (Cummings et al, 2007). Dasari et al (2024) published a study that illustrated how Tele-ICU offers organ donor management, and even in low-resource settings, used Tele-ICU as a means to decrease transfer rates and optimize organ usage. These findings demonstrate how Tele-ICU can positively benefit patient outcomes, as well as the level of care.

Reducing Nurse Workload and Burnout

Stress associated with an ICU that is frequently high-pressure setting and nurse burnout (Zang et al, 2020), accessing so much of work an added burden of nurse staffing shortages and patient acuity, Tele-ICU alleviated workload by allowing the remote groups to take on the repetitive monitoring, and bedside nurses to focus on patients (Poncette et al, 2020). Among the 1,200 Tele-ICU nurse respondents, 78% reported an increase in job satisfaction from less workload and improved interdisciplinary practice within the remote groups (Kleinpell et al, 2016). In addition, Tele-ICU nurse participants reported that remotely monitoring patients reduced interruptions while the patient's care was delivered at the bedside, and removed repetitive bedside assessment (Poncette et al., 2020).

During the COVID-19 pandemic, Tele-ICU provided a solution for utilizing the ICU effectively, while also addressing nurse fatigue and burnout (Guinemer et al., 2020). Through teleconference visitations from families or virtual consults, Tele-ICU could eliminate the emotional and physical fatigue of bedside nurses (Geetha et al., 2024). These findings have incredible repercussions for Tele-ICU, not only as a tool for promoting nurse health, but retention in high-stress roles for nurses.

Advancing Interdisciplinary Collaboration

Tele-ICU fosters increased interdisciplinary collaboration between the bedside team with patients and families, and the remote team, with communication ability and decision-making (Mullen-Fortino et al., 2020). Families, patients and bedside staff can communicate seamlessly through advanced communication technology with the Tele-

ICU team's nurses, resulting in less time from environmental or emotional stress interruptions in patient care (Shahpori et al., 2011). For example, Mullen-Fortino et al. (2020) qualitative study indicated that Tele-ICU nurses' systems thinking disposition, in conjunction with their technical expertise, enabled more efficient patient care coordination. This would be especially profound in the milieu of high-stress use of mechanical ventilator, or extracorporeal membrane oxygenation support. This also increases the potential for tele-ICU interventions on quality improvement initiatives, such as HAI prevention (Poncette et al., 2020).

Implementation Issues

Technical and Financial Obstacles

The deployment of Tele-ICU systems raises substantial technical and financial obstacles that may limit widespread deployment, especially in places with minimal resources. The associated capital cost of implementing Tele-ICU systems was significant as it includes a high-definition audio-visual network, high-end software platform, secure network infrastructures, and interoperability of installed electronic health records systems. The installed cost of Tele-ICU systems incorporating research to be approximately $2 - $5 million per hospital (2014), and this does not include ongoing system maintenance, software management, and technical support (Lilly et al., 2014). For rural or smaller centres that operate on a restricted budget, these financial constraints may render them all but helpless, disadvantaging their access and performance to newer Critical Care technologies (Kumar et al., 2013). The substantial demands for a strong internet connection, while diminishing seamless system interoperability present a further layer of complexity. Technical difficulties such as diminished audio-visual quality, delay in data transfer, or unexpected 'crashes' that compromise real-time patient monitoring and care, respectively (Kleinpell et al, 2016). These challenges can only be overcome through the availability of a comprehensive IT backbone, high-bandwidth networks, and dedicated teams of technical support professionals, to ensure the reliability of the systems and continuity of care. Viable financing arrangements, such as public-private partnership arrangements or government funding, best support the implementation and maintenance of Tele-ICU systems, especially in resource-poor contexts.

Employee Resistance and Training Needs

Resistance from bedside workers represents the biggest barrier to successfully implementing Tele-ICU systems. Many bedside nurses and clinicians view tele-monitoring as too intrusive, believing Tele-ICU takes their autonomy away from decision-making or places them under too much scrutiny (Shahpori et al., 2011). These beliefs can create mistrust between bedside teams and remote teams and reduce partnership and benefit from the Tele-ICU intervention. In a study of a Tele-ICU implementation in the Kingdom of Saudi Arabia, 62% of bedside nurses were distrustful of Tele-ICU based on their unfamiliarity with the technological components and fear of being micromanaged by remote teams (Al-Mutair et al., 2020). These perceptions can be compounded by poor training that leaves the team unprepared to incorporate the Tele-ICU workflows into their practice. Successful implementation of Tele-ICU requires extensive training focused on technical capability as much as cultural acceptability. Education should include simulation, the protocols of the roles and responsibilities of each team (Tele-ICU and bedside), along with trust-building and teamwork (Cummings et al., 2007). Additionally, frontline personnel who will be using the Tele-ICU system should also be engaged in both the planning and implementation phases to alleviate any concerns raised as early as possible, promote the acceptability of the Tele-ICU system, and promote a sense of ownership. Ongoing education and feedback processes will also be necessary to grow with the emerging technologies and foster personnel confidence with the system.

Variability of Measuring Outcomes

Measurement of Tele-ICU system effectiveness is additionally complicated by the absence of standardized measures of outcomes, which would enable findings to be compared across studies and health care settings. Measures used in studies of Tele-ICU have also varied (ICU mortality rates, length of stay (LOS), cost savings, protocol adherence), but in many cases, the measures are inconsistently defined and/or applied (Kumar et al., 2013). Mortality has been viewed by some studies without making adjustments for patients' severity or comorbidity, thus creating controversy about the effect of Tele-ICU (Thomas et al., 2009). In the face of such inconsistency, it becomes difficult to draw decisive conclusions about the clinical and economic efficacy of Tele-ICU, further complicating the process of rationalising the high costs of implementing it. To address this ongoing challenge, standardized reporting systems that (a) utilize defined, risk-adjusted measures of outcomes and (b) apply the same rigor of reporting, such as standardized mortality ratios, ventilator-free days, and patient-specific complication rates, need to be developed as a priority (Lilly et al., 2014). If and when these systems become commonly used, among other things, they would give a better opportunity for reliable comparisons across institutions and would provide more evidence that supports the introduction of Tele-ICU from policy and economic perspectives.

Emerging Trends: Ubiquitous Sensing and AI

The Tele-ICU systems presented above are already continuously replaced through hybridisation of ubiquitous sensing technologies and artificial intelligence (AI), which represents radical improvements in capability and inherent groundbreaking opportunities for patient care whilst enhancing nursing workflows. AI-oriented algorithms can process large data sets from the EHR, vital signs monitoring, wearable monitoring and imaging modalities providing real-time and predictive intelligence. For example, researchers reported results finding that AI-based models were able to identify patients at risk for deterioration, such as sepsis or acute respiratory failure, up to 90 minutes ahead of their actual event based on identifying patterns of vital signs and lab values (Yoon et al., 2022). For example, Davoudi et al. (2019) reported results finding that AI-based monitoring was able to differentiate between the delirious and the non-delirious patient through monitoring of the face, body orientation/positionality, and environmental parameters accessed through video streams and sensors. These technologies lessen the cognitive burden of the nurse through reducing unnecessary repeat testing, which is possible through the identification of early declines in patient condition, also allowing for a more accurate and timely intervention (Poncette et al., 2020).

Pervasive sensing technologies such as ambient sensors and wearables provide another natural fit for enhanced Tele-ICU through unobtrusive, continuous monitoring of patient parameters. Robotic systems, also typically accompanied by AI, are viewed as potential tools of urgently needed care. These can facilitate tasks such as physical rehabilitation exercises, patient repositioning, and automated medication administration in ways that may improve care efficiency and lessen the physical burden on bedside staff (Chen et al., 2023). Notwithstanding their use cases, both AI and ubiquitous sensing technologies come with challenges, including most prominently data privacy concerns, algorithm bias, and the need to connect to existing Tele-ICU platforms (Yoon et al., 2022). In particular, patients need to trust that the strong encryption methods applied will correspond with the data they expect and that their data will comply (e.g., with HIPAA). In addition, the AI algorithm needs to be validated to mitigate the risk of bias, which can lead to an inequitable distribution of care. Future research needs to explore the development of interoperable systems that include ethical considerations and investigate the long-term implications of the technologies, not only on the output of care but also on nurse workload (Table 1).

Table 1: Challenges and Strategies for Tele-ICU Implementation

Challenge	Description	Strategy	Reference
Financial Constraints	Initial setup costs of $2–5 million per hospital	Explore cost-sharing partnerships, apply for government or private grants	Lilly et al. (2014)
Technical Limitations	Disruptions in audio-video connectivit	Upgrade IT infrastructure, implement redundant	Kleinpell et al. (2016)

	y and system outages	systems for reliability	
Staff Reluctance	Perceptions of remote oversight as intrusive, lack of trust in the system	Provide comprehensive staff training, establish clear roles and communication protocols	Mullen-Fortino et al. (2021)
Inconsistent Metrics	Variability in outcome measures across studies	Create standardized evaluation frameworks for outcomes like mortality and LOS	Kumar et al. (2013)

Case Studies in Real-World Application and Tele-ICU

Tele-ICU and COVID-19

COVID-19 highlighted the pivotal role of the Tele-ICU systems in addressing the historic challenge of skyrocketing ICU admissions while preparing for unprecedented shortages of critical care staff and critical care supplies (Guinemer et al., 2020). While global healthcare systems dealt with enormous patient surges, the Tele-ICU acted as an important allocator of resources, enhancer of care, and real-time bedside clinician supporter. In a scoping review of the applications of the Tele-ICU, Guinemer et al. (2020) identified that the top five applications of the Tele-ICU were: teleconsultation, telerounds, telemonitoring, virtual family visits, and infrastructure adaptation. Teleconsultation offered intensivists at a distance the ability to make authoritative recommendations to bedside teams, speeding up the management of complex cases, e.g., the adjustment of ventilator settings to infuse life support into the patients of COVID-19, particularly in resource-limited hospitals with little critical care knowledge with no previous direct experience. Tele rounds allowed intensivists and nurses at a distance the ability to the present at bedside rounds every day through audiovisual modalities, permitting continuity of care and use of evidence-based recommendations. Telemonitoring allowed for monitoring of the patient's vital signs, lab, and imaging in real-time, allowing for the earliest recognition of patient decline and immediate plans for intervention.

Virtual family visits worked as a mental injury control of isolation via video-based patient and family communication while awaiting the arrival of in-person visit limitations through the prevention of transmission means. They also had to adapt infrastructure, rethinking Tele-ICU technology to accommodate temporary ICU expansions (e.g., transforming a nursing unit outside an ICU temporarily into an ICU during swells). Those returns reported by studies ranged from losses of 15 - 30% mortality in ICUs at high patient volumes, related to specialty engagement of care and maximal resource use (Geetha et al., 2024). Tele-ICU also lightened the load for bedside nursing, especially for internationally experienced intensivist shortages and critical care nurse shortages. The following example bears the most credible weight: One suburban hospital entered a partnership with Remote-ICU, keeping 80% of their severely COVID-19-experiencing patients that would have to be transferred to tertiary centers for lack of critical care capacity, avoiding a loss of local care and offloading regional health systems (RemoteICU, 2021). Thus, the situation represents the Tele-ICU Lifeline to the pandemic, successfully in resource-constrained situations, supporting high-acuity patients (Table 2).

Table 2: Tele-ICU Applications During COVID-19

Application	Description	Impact	Citation
Teleconsultation	Remote consultations with specialists	Reduced staff exposure, improved decision-making	Guinemer et al. (2020)

Telerounding	Virtual rounds by intensivists	Enhanced care coordination, reduced LOS	Geetha et al. (2024)
Telemonitoring	Real-time patient monitoring	Early detection of deterioration, 15–30% mortality reduction	Guinemer et al. (2020)
Virtual Family Visitation	Video-based family communication	Reduced emotional strain on nurses	Geetha et al. (2024)
Infrastructure Adaptation	Scaling ICU capacity remotely	Retained 80% of patients in community hospitals	RemoteICU (2021)

Rural and Underserved Communities

Tele-ICU has innovatively played a role in addressing the expertise and resource gaps that exist in rural and underserved areas, which lack immediate access to highly specialized critical care expertise. Often, there will not be an intensivist physically present at the rural centers, and transferring unstable patients to distant, tertiary centers can be costly, impractical, and detrimental to patient-centred care (Ofoma et al., 2021). Tele-ICU addresses this by ensuring access to board-certified intensivists and critical care nurses in real time, and thereby providing high-quality care at resource-poor sites.

A remarkable case study by RemoteICU (2021) describes the challenges and impact of Tele-ICU in a rural, seven-bed ICU hospital. The hospital reported that before Tele-ICU, its only option was to refer patients to larger centers, as it lacked an intensivist physically present in the hospital. After implementing the Tele-ICU service, the hospital was able to manage the patients locally, as it referred very few (if any) patients. Overall, the study was able to demonstrate a 20% reduction in ICU length of stay (LOS), in which early intervention from remote monitoring and consultation with experts allowed for valuable patient-centred care (RemoteICU, 2021). By keeping the patient in the patient's locality, not only was a more efficient response to the patient's health, but also the cost and psychological burden to the patient and family due to the long distance of transport. The hospital experienced increased need satisfaction and confidence among health professionals because the bedside nurse was always able to receive virtual support and guidance from critical care teams many miles away.

The results speak to helping Tele-ICU mitigate critical care disparity, particularly in rural and underserved populations. Tele-ICU reduces prevention, treatment, and health equity inequities in rural patients, allowing health access as close to home as possible and receiving evidence-based therapies promptly. However, scaling up in these settings will need to resolve limited internet connectivity to provide virtual health, excessive cost to set up the platforms, and the requirement of customized institutionally specific training and potential professional development for acceptability and competency of health workers. Future endeavors should be aimed at developing cost-saving pathways for Tele-ICU as well as utilizing government funds or donor funds to financially support the uptake of the Tele-ICU program in low-resource settings, thereby further increasing the breadth and depth of specialized critical care expertise.

Future Directions

In order to unlock the transformative potential of Tele-ICU, there are many strategic actions that must be taken to overcome the limitations of the current state and enhance the transformative nature of Tele-ICU on critical care delivery. First, it will be necessary to align measures of outcomes, including mortality, length of stay (LOS), and cost-effectiveness, to improve the temporal comparisons of Tele-ICU research studies that have concrete Tele-ICU utility and quality evidence (Lilly et al., 2014). Aligning consistent and risk-adjusted measures will allow researchers and clinicians, and health-system admins will be able, to more accurately gauge the effectiveness of Tele-ICU across diverse settings, generating data to provide meaningful feasibility for implementation decisions. The second, the future must feel considerable gains in the way of extensive invested education and training programs of both bedside personnel and Tele-ICU personnel to enable acceptability and increase interdisciplinary collaboration (Mullen-Fortino et al., 2021). These must have elements of hands-on simulation, role clarification, and education to build technical competence and confidence with the technology, in order to alleviate resistance and promote teamwork.

Third, meticulously conduct cost-effectiveness analyses to assess the cost implications of Tele-ICU, weighing the start-up costs against ongoing costs and the eventual benefit of reducing transfers, reducing length of stay, decline in outcomes, etc. (Kumar et al., 2013). These analyses will make the business case blatantly attractive, especially to asset-light hospitals. Fourth, the adoption of AI technologies within the Tele-ICU environment can also help automate nurse workload and considerably improve predictive capability (Davoudi et al., 2019). AI technologies, such as predictive algorithms and automated monitoring systems, can trigger earlier detection of patient deterioration, improve allocation of resources, make some monitoring and resource allocation tasks more efficient, and harness the cost-effectiveness of these tools while being cognizant of algorithmic bias and data privacy considerations. Finally, funding reimbursement through policy and regulation must be offered for investing in Tele-ICU, particularly in rural and underserved environments with critical care shortages (Al-Mutair et al., 2020). Governments and healthcare systems must create incentives, e.g., subsidies or telehealth reimbursement policy, to make the investment in Tele-ICU infrastructure viable and make high-end critical care equally accessible. By adopting these interventions, the application of Tele-ICU can be transformed from the future of promising critical care to the future of critical care foundation, enhancing patient outcomes and strengthening global healthcare systems.

Conclusion

Tele-ICU and remote monitoring have transformed nursing care of the very ill through the improvement of patient safety, nurse workload reduction, and the streamlining of interdisciplinary care. Regardless of the fears of expense, technical failure, and resistance among the staff, the value of Tele-ICU, through lowered mortality and LOS, continues to readily justify it. Future technologies, such as AI and ubiquitous sensing, have promise for the continued improvement of the utilization of Tele-ICU. Through the overcoming of the implementation and investment challenges and expenditure in education and standardization, health systems can attain the full potential of Tele-ICU to enhance outcomes and support nursing staff in high-acuity settings.

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