Assessing the Impact of Evidence-Based Nursing Interventions on Pressure Ulcer Prevention in Hospitals

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October 21, 2025

Abstract

This comprehensive study investigates the efficacy of evidence-based nursing interventions in preventing pressure ulcers within hospital settings, employing a novel computational framework that integrates machine learning with clinical decision support systems. Unlike traditional approaches that rely on retrospective analysis, our methodology introduces a predictive modeling system that anticipates pressure ulcer development risk in real-time, enabling proactive intervention. We developed and implemented a multi-faceted intervention protocol incorporating advanced sensor technology, automated risk assessment algorithms, and personalized care planning. The research was conducted across three major hospital systems over a 24-month period, involving 2,347 patients and 487 nursing staff members. Our results demonstrate a statistically significant 68

1 Introduction

Pressure ulcers represent a significant challenge in contemporary healthcare delivery, affecting approximately 2.5 million patients annually in the United States alone and contributing substantially to healthcare costs, patient morbidity, and extended hospital stays. Traditional approaches to pressure ulcer prevention have relied heavily on standardized risk assessment tools such as the Braden Scale, combined with manual repositioning protocols and basic skin care interventions. While these methods have demonstrated some efficacy, their reactive nature and dependence on human vigilance limit their overall effectiveness in dynamic clinical environments. The persistent incidence of hospital-acquired pressure ulcers indicates a critical need for innovative approaches that leverage technological advancements to enhance preventive care.

This research introduces a novel computational framework that transforms pressure ulcer prevention from a reactive to a proactive paradigm. Our approach integrates real-time patient monitoring, machine learning algorithms, and automated clinical decision support to create an intelligent prevention system. The fundamental research question guiding this investigation examines how computational technologies can enhance the implementation and effectiveness of evidence-based nursing interventions for pressure ulcer prevention. Specifically, we explore whether predictive analytics can identify at-risk patients before visible tissue damage occurs and whether automated intervention protocols can improve adherence to evidence-based practices while reducing nursing workload.

Our methodology represents a departure from conventional research in this domain by employing a hybrid approach that combines elements of computer science, biomedical engineering, and nursing science. The development of our predictive model incorporates not only traditional risk factors but also real-time physiological data, movement patterns, and environmental variables that have not been systematically integrated in previous prevention strategies. This comprehensive data integration enables a more nuanced understanding of pressure ulcer pathogenesis and facilitates targeted interventions tailored to individual patient risk profiles.

The significance of this research extends beyond pressure ulcer prevention to broader implications for healthcare technology implementation. As healthcare systems increasingly embrace digital transformation, understanding how computational tools can enhance rather than replace clinical judgment becomes paramount. Our study addresses this intersection by developing a system that augments nursing expertise with computational intelligence, creating a synergistic relationship between human caregivers and technological systems. This approach acknowledges the complex, contextual nature of nursing care while leveraging technology to handle data-intensive tasks and pattern recognition.

2 Methodology

Our research employed a multi-phase, mixed-methods approach conducted across three major hospital systems over a 24-month period. The study design incorporated both quantitative outcome measures and qualitative process evaluation to provide comprehensive insights into the implementation and effectiveness of our computational prevention system. The participant cohort included 2,347 adult patients admitted to medical-surgical, critical care, and long-term care units, with representation across diverse age groups, clinical conditions, and mobility statuses. Nursing staff participation involved 487 registered nurses and nursing assistants who received specialized training in the new prevention protocol.

The core innovation of our methodology lies in the development and implementation of the Intelligent Pressure Ulcer Prevention System (IPUPS), which integrates multiple technological components into a unified prevention framework. The system architecture comprises three primary layers: data acquisition, analytical processing, and clinical intervention. The data acquisition layer incorporates advanced pressure-sensing technology embedded in hospital mattresses and chairs, continuous monitoring of tissue oxygenation using near-infrared spectroscopy, and automated capture of patient repositioning through motion sensors. These technological components work in concert to create a comprehensive digital representation of each patient's pressure injury risk profile.

The analytical processing layer employs machine learning algorithms specifically designed for healthcare applications. We developed a hybrid predictive model that combines gradient boosting machines for handling structured clinical data with convolutional neural networks for processing time-series sensor data. The model was trained on a historical dataset of 15,000 patient records with validated pressure ulcer outcomes, achieving robust performance through rigorous cross-validation and hyperparameter optimization. Feature engineering incorporated both static variables (such as age, comorbidities, and nutritional status) and dynamic variables (including real-time pressure distribution, tissue perfusion metrics, and movement patterns).

The clinical intervention layer translates analytical insights into actionable nursing care through an automated decision support system. When the predictive model identifies a patient as high-risk, the system generates personalized intervention protocols that consider the patient's specific risk factors, current condition, and unit resources. These protocols include optimized repositioning schedules, specialized support surface recommendations, and nutritional interventions, all presented through an intuitive interface that integrates with existing electronic health record systems. The system also includes automated documentation features that capture intervention implementation and patient responses, creating a continuous feedback loop for model refinement.

Implementation of the IPUPS followed a structured rollout process that included comprehensive staff education, technical support, and ongoing quality monitoring. We employed a stepped-wedge cluster randomized design, with units transitioning from conventional care to the new system at staggered intervals. This design allowed for within-unit comparisons while controlling for temporal trends and seasonal variations in pressure ulcer incidence. Data collection included quantitative measures of pressure ulcer incidence, severity, and location; nursing intervention adherence; and system usability metrics. Qualitative data gathered through focus groups and structured interviews provided insights into nursing staff experiences, perceived benefits, and implementation challenges.

Statistical analysis employed mixed-effects models to account for the clustered nature of the data and repeated measurements over time. Primary outcomes included the incidence of hospital-acquired pressure ulcers of stage II or higher, time to ulcer development, and preventive intervention adherence rates. Secondary outcomes encompassed nursing workload measures, system usability scores, and cost-effectiveness indicators. All analyses were conducted using intention-to-treat principles, with sensitivity analyses performed to assess the robustness of findings to various assumptions and missing data patterns.

3 Results

The implementation of our computational prevention system yielded substantial improvements in pressure ulcer outcomes across all study sites. The overall incidence of hospital-acquired pressure ulcers decreased from 8.7

The predictive performance of our machine learning model exceeded expectations, achieving an area under the receiver operating characteristic curve of 0.943 for identifying patients who would develop pressure ulcers within the subsequent 48 hours. The model demonstrated particularly strong performance in detecting early tissue damage before visible skin changes, with 91

Intervention adherence rates showed remarkable improvement under the new system. Documentation of scheduled repositioning increased from 64

Qualitative findings provided important context for understanding the quantitative outcomes. Nursing staff expressed strong support for the predictive alerts, describing them as valuable clinical decision aids rather than intrusive notifications. Many nurses reported that the system enhanced their clinical assessment skills by drawing attention to subtle risk factors they might otherwise have overlooked. The personalized intervention protocols were particularly valued for their adaptability to individual patient needs and unit workflows, contrasting with the one-size-fits-all approach of traditional prevention protocols.

Unexpected benefits emerged in several areas beyond the primary outcomes. The continuous monitoring data revealed previously unrecognized patterns in pressure ulcer development, including the significance of brief periods of elevated pressure during routine care activities and the protective effect of micro-movements that are not captured by traditional repositioning documentation. These insights have implications for refining prevention strategies and suggest that our current understanding of pressure ulcer pathophysiology may be incomplete.

Cost-effectiveness analysis indicated that the system generated substantial savings despite initial implementation costs. The reduction in pressure ulcer incidence translated to an estimated cost avoidance of $3,200 perpreventedulcer, consideringdirecttreatmentcostsandextendedlengthofst$

4 Conclusion

This research demonstrates the transformative potential of integrating computational technologies with evidence-based nursing practice for pressure ulcer prevention. Our findings establish that a systematically implemented, technology-enhanced prevention protocol can substantially reduce hospital-acquired pressure ulcers while simultaneously improving nursing workflow efficiency. The 68

The success of our predictive model highlights the value of machine learning in healthcare applications, particularly for conditions with multifactorial etiology and progressive development. The ability to identify at-risk patients before visible tissue damage occurs represents a fundamental shift from reactive to preventive care, aligning with broader healthcare goals of anticipating and preventing adverse events rather than simply treating them. The high accuracy of our model, combined with its clinically meaningful prediction window, provides nursing staff with actionable intelligence that enhances rather than replaces their clinical judgment.

Our research contributes several original insights to the literature on pressure ulcer prevention and healthcare technology implementation. First, we demonstrate that real-time physiological monitoring, when properly integrated with clinical workflows, can provide unique insights into pressure ulcer pathogenesis that are not apparent through intermittent assessment. Second, we establish that automated clinical decision support can significantly improve adherence to evidence-based practices without increasing nursing workload, addressing a common barrier to implementation of preventive protocols. Third, our findings suggest that the relationship between technology and nursing practice can be synergistic rather than antagonistic, with computational systems augmenting human expertise to achieve superior patient outcomes.

The implications of this research extend beyond pressure ulcer prevention to broader applications in patient safety and nursing informatics. The framework we developed for integrating sensor data, predictive analytics, and clinical decision support could be adapted for other healthcare-associated conditions, such as falls prevention, delirium management, or venous thromboembolism prophylaxis. The principles of augmenting clinical judgment with computational intelligence, while maintaining human oversight of critical decisions, provides a template for responsible implementation of artificial intelligence in healthcare settings.

Several limitations warrant consideration in interpreting our findings. The study was conducted in large academic medical centers with robust information technology infrastructure, and generalizability to smaller or resource-limited settings requires further investigation. The Hawthorne effect may have influenced nursing behavior during the study period, though the sustained improvement over 24 months suggests that the observed benefits reflect genuine practice change rather than temporary heightened awareness. Additionally, the long-term maintenance of system effectiveness and staff engagement remains to be evaluated beyond the study period.

Future research directions include refining the predictive models through continuous learning from new patient data, exploring applications in non-hospital settings such as long-term care or home health, and investigating the integration of additional data sources such as electronic health record narratives or laboratory trends. The potential for similar approaches in low-resource settings, using simplified sensor technology and mobile platforms, represents another promising avenue for expanding the impact of this research.

In conclusion, our study provides compelling evidence that computational technologies, when thoughtfully designed and implemented, can dramatically enhance the effectiveness of evidence-based nursing interventions for pressure ulcer prevention. The successful integration of machine learning, sensor technology, and clinical decision support created a prevention system that not only improved patient outcomes but also supported nursing workflow and clinical decision-making. As healthcare continues to evolve toward more predictive, personalized, and participatory models, approaches such as the one described here will be increasingly essential for achieving optimal patient safety and quality outcomes.

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