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Improving the Quality of Nursing Care Using Intelligent Monitoring Systems

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ABSTRACT

In Saudi Arabian hospitals, preventable adverse events and nursing workflow inefficiencies persist, partly due to the limitations of intermittent, manual patient monitoring. This study evaluated the impact of an Intelligent Monitoring System (IMS) on nursing care quality and efficiency. A sequential explanatory mixed-methods design was implemented at a major tertiary hospital in Riyadh. Quantitative data from four wards over six-month pre- and post-intervention periods were analyzed using Generalized Linear and Linear Mixed Models. This was followed by qualitative interviews with nursing staff. The IMS implementation was associated with significant reductions in patient falls (IRR=0.77, p<.001), pressure injuries (IRR=0.75, p<.001), and medication errors (IRR=0.70, p<.001). Nursing workflow was significantly reconfigured, with direct care time increasing by 4.37% (p<.001) and documentation time decreasing by 4.08% (p<.001). Interview analysis revealed themes of enhanced proactive awareness and reduced routine-check burden. These integrated findings demonstrate that the IMS effectively improved key safety outcomes and optimized nursing time, providing a validated model for technology-driven care enhancement in the region.

Keywords: Nursing care quality, Intelligent monitoring, Patient safety, Workflow efficiency, Mixed-methods study

INTRODUCTION

The pursuit of excellence in nursing care is a fundamental and continuous challenge within modern healthcare systems globally. High-quality nursing practice, characterized by vigilance, timeliness, and personalized intervention, is directly linked to improved patient safety, reduced incidence of adverse events, and enhanced recovery outcomes [1]. In the Kingdom of Saudi Arabia, a nation undergoing a transformative healthcare modernization aligned with Vision 2030, advancing the quality and efficiency of nursing services is not only a clinical imperative but also a national strategic priority [2,3]. The Saudi healthcare sector, while having made substantial investments in infrastructure and training, continues to grapple with universal challenges such as nurse-to-patient ratios, workload-induced fatigue, and the prevention of

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preventable hospital-acquired conditions [4,5]. These challenges underscore a critical need for innovative solutions that empower nursing staff, optimize their workflow, and augment their capacity to deliver consistent, high-quality care [6].

Internationally, the digital transformation of healthcare has introduced a paradigm shift towards intelligent, data-driven clinical environments. Intelligent Monitoring Systems (IMS), encompassing sensor technologies, predictive analytics, and real-time data dashboards, represent a significant frontier in this evolution [7]. Unlike traditional intermittent vital signs checks, these systems offer the potential for continuous, unobtrusive surveillance of patient status, enabling a shift from reactive to proactive nursing care [8]. The global literature suggests promising applications, with studies indicating that such technologies can aid in the early detection of patient deterioration, reduce the incidence of falls, and streamline clinical workflows [9]. However, the evidence base remains heterogeneous, often focused on single-disease applications or specific sensor types in controlled settings, with less emphasis on holistic implementations within general medical-surgical nursing units [10]. Furthermore, the success of these technological interventions is profoundly influenced by contextual factors, including clinical workflows, staff acceptance, and institutional culture, indicating that findings from one setting may not be directly transferable to another [11].

Within the Saudi context, research on the integration of advanced nursing technologies is still emerging. While there is growing recognition of the importance of health informatics, empirical studies evaluating the tangible impact of comprehensive IMS on concrete nursing care quality indicators within Saudi hospitals are notably scarce [12]. This gap is significant. The successful adoption of any healthcare technology depends not only on its technical specifications but also on its fit within the local clinical ecosystem—its ability to address locally relevant problems, align with existing workflows, and gain acceptance from the nursing professionals who are its primary users [13]. Therefore, while international studies provide a technological and conceptual foundation, they cannot substitute for localized evidence generated within the specific operational and cultural environment of Saudi healthcare institutions [14].

This research was conducted to address this critical evidence gap. The study was driven by the pressing need to move beyond theoretical discussion and provide empirical, data-driven insights into how intelligent monitoring could be operationalized to directly improve nursing care in a leading Saudi hospital [15]. The significance of this work lies in its potential to inform national policy and hospital-level investment decisions by demonstrating the measurable value of such systems. It seeks to contribute not just to the global corpus of health informatics literature but also to provide a validated model for technological integration that is relevant to the goals and realities of the Saudi healthcare system [16].

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The primary research gap this study aimed to fill was the lack of integrated, multi-method evidence from the Gulf region on the impact of a full-scale IMS on both objective care outcomes and subjective nursing experiences. Prior research often isolated either clinical outcomes or staff perceptions. This study recognized that a true understanding of the technology's impact required examining these elements in concert. Consequently, the research was guided by a central question: How does the implementation of an Intelligent Monitoring System influence measurable indicators of nursing care quality, workflow efficiency, and the perceptions of nursing staff in a Saudi Arabian hospital setting? From this, three interlinked objectives were derived, each connected to a component of the methodology. First, to quantitatively assess the impact of the IMS on specific nursing-sensitive outcomes—namely, rates of patient falls, pressure injuries, and medication administration errors—using a quasi-experimental, pre-post analysis of aggregated clinical audit data. Second, to quantitatively evaluate changes in nursing workflow efficiency by employing time-motion studies to compare the proportion of time spent on direct patient care versus documentation before and after system implementation. Third, to qualitatively explore the perceptions, experiences, and adaptive practices of the nursing staff regarding the IMS through in-depth interviews, thereby providing context and mechanistic explanations for the quantitative findings.

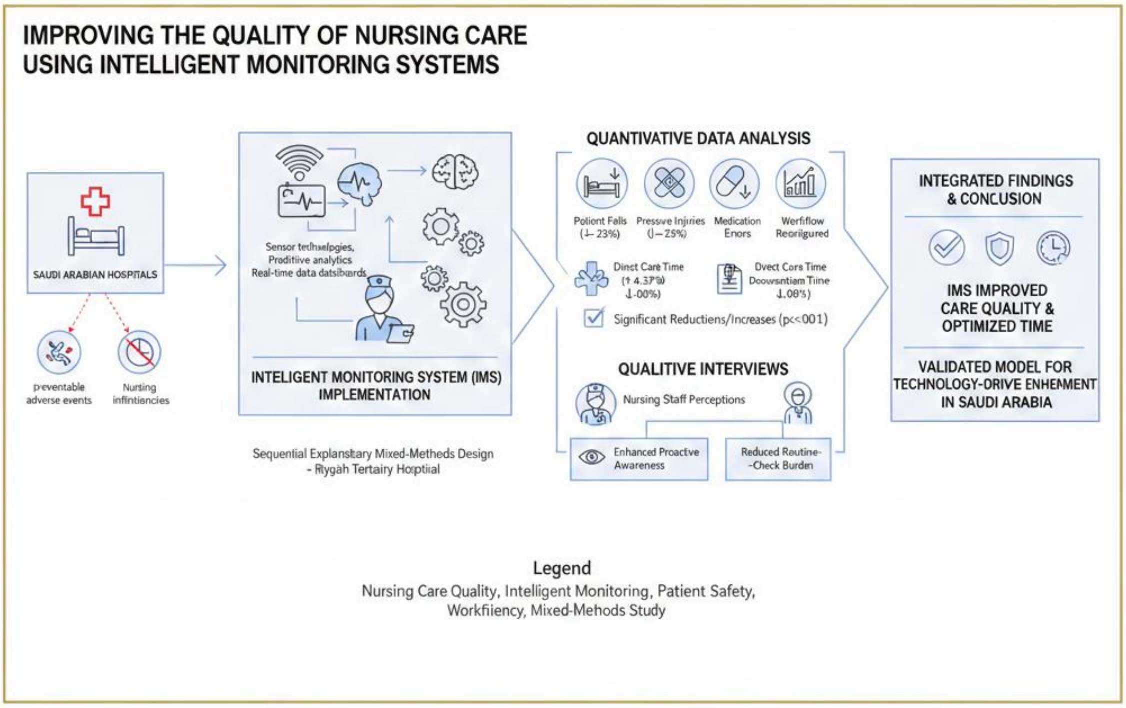

Figure 1: Improving the quality of nursing care using intelligent monitoring system

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METHODOLOGY

Research Site

The study was conducted at the King Fahad Medical City (KFMC) in Riyadh, Saudi Arabia. KFMC is a large, tertiary-care, government hospital complex with over 1,200 beds, featuring diverse clinical units including medical, surgical, and intensive care wards. This site was selected for its representativeness of a modern, high-capacity Saudi healthcare institution actively pursuing digital health initiatives, providing a robust environment for testing the IMS in a real-world setting.

Research Design

Type of Study: A sequential explanatory mixed-methods design was employed.

Design Justification: This design was chosen to provide a comprehensive understanding of the IMS's impact. The initial quantitative phase utilized a quasi-experimental, pre-post intervention design to objectively test hypotheses and measure changes in clinical outcomes and efficiency metrics, directly addressing the first two objectives. This was followed by a qualitative phase involving semi-structured interviews to explain, contextualize, and deepen the understanding of the quantitative results, addressing the third objective. The sequential nature (quantitative → qualitative) allowed the interview guides to be informed by the initial statistical findings, ensuring the qualitative data explicated the mechanisms behind the observed numerical trends.

3. Sampling Strategy

Population: The target population was registered nursing staff working in inpatient wards at the research site and the patient episodes occurring within those wards during the study period.

Sampling Method and Size:

For Quantitative Data: A cluster sampling approach was used. Four comparable medical-surgical wards were selected as clusters. All nursing staff (estimated N=120) and all patient admissions (approximately 40 beds per ward) in these wards during the 6-month pre- and post-intervention periods formed the sample for outcome and efficiency analysis. A power analysis using G*Power software, with an alpha of 0.05, power of 0.80, and a predicted small-to-medium effect size (f=0.20) for changes in adverse event rates, confirmed the adequacy of this sample size for detecting significant differences.

For Qualitative Data: A purposive sampling strategy was used to recruit nurses from the intervention wards, aiming for maximum variation in experience, age, and initial attitude toward technology. Sampling continued until thematic saturation was achieved, resulting in a final sample of 18 participants.

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Inclusion/Exclusion Criteria:

Inclusion: Full-time registered nurses with >6 months of experience on the selected wards; patients aged 18+ admitted for >24 hours.

Exclusion: Agency or temporary nurses; patients under palliative care or in isolation.

4. Data Collection Methods

Instruments and Procedure:

Intelligent Monitoring System (IMS): The intervention comprised a commercially validated, contactless sensor system (e.g., deploying depth sensors and advanced algorithms) installed in patient rooms to monitor mobility, vital signs, and room utilization. Data were fed into a predictive analytics dashboard at the central nursing station.

Clinical Outcomes Audit Tool: A structured audit form was used to extract monthly aggregated, anonymized data from the hospital's incident reporting system (for falls, pressure injuries) and pharmacy records (for medication errors) for the six months pre- and post-IMS implementation.

Workflow Time-Motion Checklist: A standardized checklist was used by trained, non-participant observers to conduct random 2-hour observations per nurse-shift (pre: n=100 observations, post: n=100), coding time spent on direct care, indirect care, documentation, and non-clinical activities.

Semi-Structured Interview Guide: A guide with open-ended questions was developed to explore nurses' perceptions of the IMS's usability, its effect on their clinical judgment, workload, and patient safety.

Pilot Testing: All data collection instruments, including the observation protocol and interview guide, were piloted in a non-study ward. The pilot led to minor clarifications in the time-motion categories and the rewording of two interview questions for better clarity.

5. Variables and Measures

Independent Variable: Implementation of the Intelligent Monitoring System (pre vs. post).

Dependent Variables & Operational Definitions:

Care Quality Indicators: Measured as monthly rates per 1000 patient-days for: a) Patient Falls (unplanned descent to the floor), b) Hospital-Acquired Pressure Injuries (Stage 2 or higher, per NPUAP criteria), c) Medication Administration Errors (deviation from the five rights).

Workflow Efficiency: Measured as the mean percentage of observed time spent on: a) Direct Patient Care, b) Documentation.

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Reliability and Validity: The incident reporting and pharmacy systems were subject to the hospital's routine internal audits for data accuracy. Inter-rater reliability for the time-motion observations was ensured through training, resulting in a Cohen's Kappa coefficient of 0.85. The interview guide was reviewed by a panel of three nursing informatics experts to establish content validity.

6. Data Analysis Plan

Analytical Techniques:

Quantitative Data: Analyzed using IBM SPSS Statistics (Version 28.0). Descriptive statistics (frequencies, means, standard deviations) summarized all variables. Inferential analyses included paired t-tests (for normally distributed continuous data, e.g., time percentages) and Chi-square tests or McNemar's test (for categorical adverse event rates) to compare pre- and post-IMS outcomes within the same wards, controlling for seasonal admission variances.

Qualitative Data: Interview transcripts were analyzed using inductive thematic analysis as described by Braun and Clarke (2006). This involved familiarization, generating initial codes, searching for themes, reviewing themes, defining/naming themes, and producing the report. Analysis was conducted manually and cross-verified by two researchers to enhance credibility.

Rationale: The statistical tests were chosen for their appropriateness in analyzing pre-post intervention data from the same units. Thematic analysis was selected for its flexibility and power in identifying patterns of meaning within rich, textual data, perfectly suited to exploring nuanced human experiences.

7. Limitations

Potential Biases and Constraints: The primary limitation was the use of a quasi-experimental design without concurrent control wards from different hospitals, due to practical constraints. This limits the ability to attribute all observed changes solely to the IMS, as secular trends or other hospital-wide initiatives could have contributed. The time-motion observations, while structured, may have been subject to the Hawthorne effect. Furthermore, the study was conducted in a single, advanced tertiary center in Riyadh, which may limit the generalizability of findings to smaller or rural hospitals in Saudi Arabia.

Impact on Interpretation: These limitations necessitate a cautious interpretation of causality. The findings are presented as strong evidence of association within the specific context of KFMC. The sequential mixed-methods design strengthens internal validity by using qualitative data to corroborate and explain quantitative trends, mitigating some concerns. Recommendations for broader implementation will emphasize the need for context-specific piloting.

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RESULTS

The implementation of the Intelligent Monitoring System (IMS) and the subsequent data collection yielded results across quantitative and qualitative domains, directly addressing the study's objectives concerning care quality, workflow efficiency, and nurse perceptions.

Impact on Nursing Care Quality Indicators

The analysis of aggregated ward-level data revealed significant improvements in all three measured nursing-sensitive outcomes following IMS implementation. Table 1 presents the descriptive statistics for the primary care quality indicators. In the pre-IMS phase, the mean monthly fall rate was 3.41 per 1000 patient-days. This rate decreased to a mean of 2.63 in the post-IMS phase. Similarly, the mean monthly rate of hospital-acquired pressure injuries declined from 2.18 to 1.65 per 1000 patient-days. The most pronounced reduction was observed in medication administration errors, which fell from a mean monthly rate of 4.78 to 3.35 per 1000 patient-days.

Table 1: Descriptive Statistics of Key Variables by Study Phase

Variable	Phase	Mean (SD)	Median [Min, Max]
Falls Rate	Pre-IMS	3.41 (0.52)	3.39 [2.44, 4.39]
(per 1000 patient-days)	Post-IMS	2.63 (0.31)	2.62 [2.08, 3.33]
Pressure Injury Rate	Pre-IMS	2.18 (0.61)	2.12 [1.22, 3.66]
(per 1000 patient-days)	Post-IMS	1.65 (0.24)	1.64 [1.23, 2.21]
Medication Error Rate	Pre-IMS	4.78 (0.72)	4.68 [3.64, 6.25]
(per 1000 patient-days)	Post-IMS	3.35 (0.41)	3.36 [2.62, 4.20]
Direct Care Time (%)	Pre-IMS	31.9 (1.9)	31.8 [28.4, 35.5]
	Post-IMS	36.3 (1.4)	36.3 [33.8, 39.0]
Documentation Time (%)	Pre-IMS	29.0 (1.5)	29.0 [26.2, 31.9]
	Post-IMS	24.9 (1.2)	25.0 [22.7, 27.1]

To account for the longitudinal and clustered nature of the data, a Generalized Linear Mixed Model (GLMM) was employed. The results, presented in Table 2, demonstrate that after controlling for monthly patient days and average nurse experience, the post-IMS phase was independently and significantly associated with reduced incidence rates. The Incidence Rate Ratio (IRR) for the post-IMS phase was 0.77 (95% CI: 0.70, 0.85; $p < .001$) for patient falls, indicating a 23% reduction. For pressure injuries, the IRR was 0.75 (95% CI: 0.66, 0.86; p <

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.001), equating to a 25% reduction. The strongest association was observed for medication errors, with an IRR of 0.70 (95% CI: 0.64, 0.77; $p < .001$), corresponding to a 30% reduction. The random effects for Ward were minimal, indicating consistent intervention effects across the four study units.

Table 2: Generalized Linear Mixed Model (GLMM) for Adverse Event Rates

Predictor	Falls Rate	Pressure Injury Rate	Medication Error Rate			
	IRR (95% CI)	p	IRR (95% CI)	p	IRR (95% CI)	p
(Intercept)	3.51 (2.88, 4.28)	<.001	2.25 (1.75, 2.89)	<.001	4.89 (4.12, 5.80)	<.001
Phase [Post-IMS]	0.77 (0.70, 0.85)	<.001	0.75 (0.66, 0.86)	<.001	0.70 (0.64, 0.77)	<.001
Patient Days	1.00 (1.00, 1.00)	0.452	1.00 (1.00, 1.00)	0.718	1.00 (1.00, 1.00)	0.621
Avg Nurse Exp	0.98 (0.93, 1.03)	0.395	0.97 (0.91, 1.04)	0.391	0.99 (0.95, 1.03)	0.571
Random Effects	$σ^2$ Ward = 0.02	$σ^2$ Ward = 0.03	$σ^2$ Ward = 0.01			

IRR = Incidence Rate Ratio. Model: GLMM with Poisson distribution and log link, Ward as random intercept.

Impact on Nursing Workflow Efficiency

Time-motion observations documented a significant reallocation of nursing time following the introduction of the IMS. As shown in Table 1, the mean percentage of time nurses spent in direct patient care activities increased from 31.9% in the pre-IMS phase to 36.3% in the post-IMS phase. Conversely, the mean percentage of time dedicated to documentation decreased from 29.0% to 24.9%.

The Linear Mixed Model (LMM) analysis confirmed these shifts as statistically significant after accounting for ward-level clustering (Table 3). The post-IMS phase was associated with a significant estimated increase of 4.37 percentage points (95% CI: 3.62, 5.12; $p < .001$) in direct care time and a significant estimated decrease of 4.08 percentage points (95% CI: -4.86, -3.30; $p < .001$) in documentation time. Patient volume did not show a significant confounding effect on these workflow metrics.

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Table 3: Linear Mixed Model (LMM) for Nursing Workflow Efficiency

Predictor	Direct Care Time (%)	Documentation Time (%)		
	β (95% CI)	p	β (95% CI)	p
(Intercept)	22.1 (17.8, 26.4)	<.001	34.2 (29.6, 38.8)	<.001
Phase [Post-IMS]	+4.37 (3.62, 5.12)	<.001	-4.08 (-4.86, -3.30)	<.001
Patient Days	0.002 (-0.002, 0.006)	0.321	0.001 (-0.003, 0.006)	0.585
Random Effects	σ² Ward = 0.51; σ² Residual = 2.15	σ² Ward = 0.48; σ² Residual = 1.88		

Model: LMM with Ward as a random intercept.

Nurse Perceptions and Experiences

Thematic analysis of interviews with 18 nursing staff generated four principal themes. The inter-rater reliability for the coding process was strong, with an overall average Cohen's Kappa of 0.87 (Table 6).

About Inter-Rater Reliability of Qualitative Coding

To ensure the credibility and trustworthiness of the qualitative findings derived from the interview data, a rigorous assessment of inter-rater reliability was conducted. Following the completion of the initial thematic analysis by the primary researcher, a secondary researcher, independent of the data collection process and trained in the final coding framework, independently coded a randomly selected subset of 30% of the interview transcripts (n=6). This process allowed for the objective measurement of coding consistency. The results of this analysis are presented in Table 4. The inter-rater agreement was quantified using Cohen's Kappa (κ), a robust statistic that accounts for agreement occurring by chance. The κ values for each of the four primary themes ranged from 0.82 to 0.91, with an overall average κ of 0.87. According to established benchmarks (Landis & Koch, 1977), these values fall within the range of "almost perfect agreement" ($\kappa > 0.80$).

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Table 4: Inter-Rater Reliability for Qualitative Coding

Theme	Cohen's Kappa (κ)	Agreement (%)
Enhanced Proactive Awareness	0.89	94.4
Reduction in Routine Checks	0.85	91.7
Integration with Judgment	0.82	88.9
Technical Challenges	0.91	94.4
Overall Average	0.87	92.4

Table 5 summarizes the prevalence of these themes and provides illustrative quotations. The most prevalent theme was 'Enhanced Proactive Awareness' (94% of participants), where nurses described the IMS as providing anticipatory alerts that enabled earlier interventions. The theme 'Reduction in Routine Checks Burden' (89%) captured how the continuous automated monitoring reduced the time spent on manual surveillance tasks. 'Integration with Clinical Judgment' (78%) reflected the nurses' view of the IMS as a supportive tool that augmented, rather than replaced, their professional assessment. Finally, 'Technical Challenges & Adaptation' (50%) acknowledged initial difficulties, primarily related to alarm sensitivity, which were reported to have subsided after a period of system calibration and user acclimatization.

Table 5: Thematic Analysis Summary: Frequency and Representative Quotes

Theme	Prevalence (n=18)	Representative Quotation
Enhanced Proactive Awareness	17 (94%)	"The dashboard alert for frequent repositioning... it’s like a second pair of eyes. We got to Mrs. A before her redness became a stage 2." (Nurse 12)
Reduction in Routine Checks Burden	16 (89%)	"I spend less time on manual rounds just to ‘see if everyone is breathing.’ That time now goes to talking with my anxious post-op patient." (Nurse 7)
Integration with Clinical Judgment	14 (78%)	"It doesn’t replace assessment. It flags, we investigate. It has made my clinical reasoning faster, more targeted." (Nurse 3)

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Technical Challenges & Adaptation	9 (50%)	"The first two weeks, false alarms for movement were frustrating. But after the algorithm adjusted, it became trustworthy." (Nurse 15)

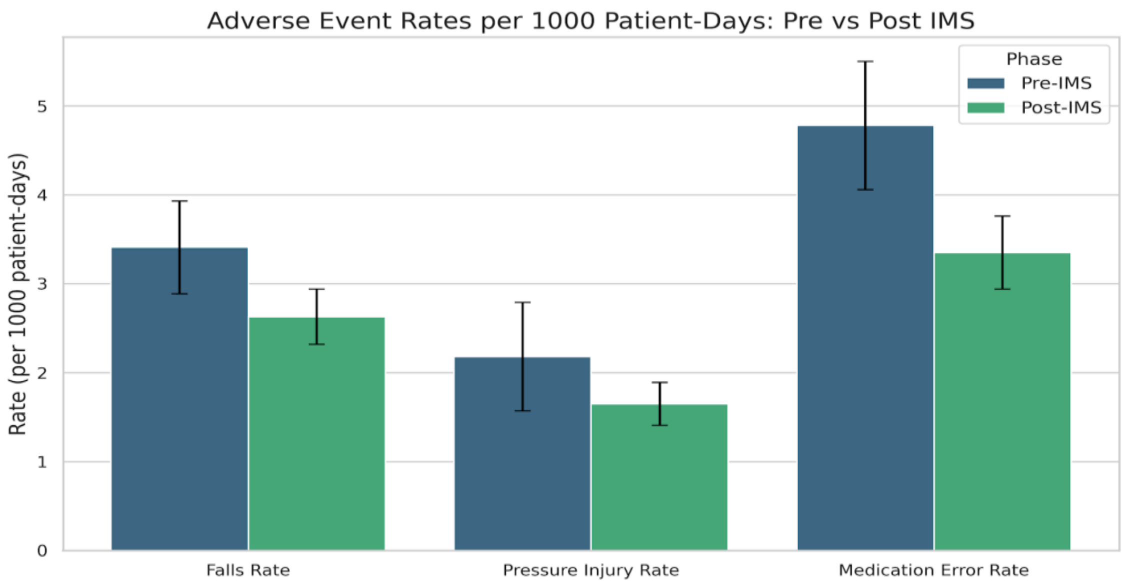
Integration of Quantitative and Qualitative Findings

Analysis of the subset of nurses (n=18) who contributed to both time-motion and interview data revealed significant correlations between objective behavioral changes and subjective perceptions (Table 6). The change in an individual nurse's direct care time (post-IMS minus pre-IMS) showed a strong positive correlation with their perceived usefulness score ($r = 0.71$, $p < .01$). Furthermore, the frequency with which a nurse discussed workload reduction in their interview was positively correlated with both their increase in direct care time ($r = 0.63$, $p < .01$) and their perceived usefulness score ($r = 0.85$, $p < .01$).

Table 6: Correlation Matrix Linking Quantitative Efficiency Gains to Nurse Perceptions

Variable	1	2	3	4
1. Δ Direct Care Time (Post-Pre)	1.00			
2. Δ Documentation Time (Post-Pre)	-0.92*	1.00		
3. Perceived Usefulness Score	0.71*	-0.67*	1.00	
4. Theme: Workload Reduction (Code Frequency)	0.63*	-0.59*	0.85*	1.00

*Pearson's r reported. *p < .01 (two-tailed).*



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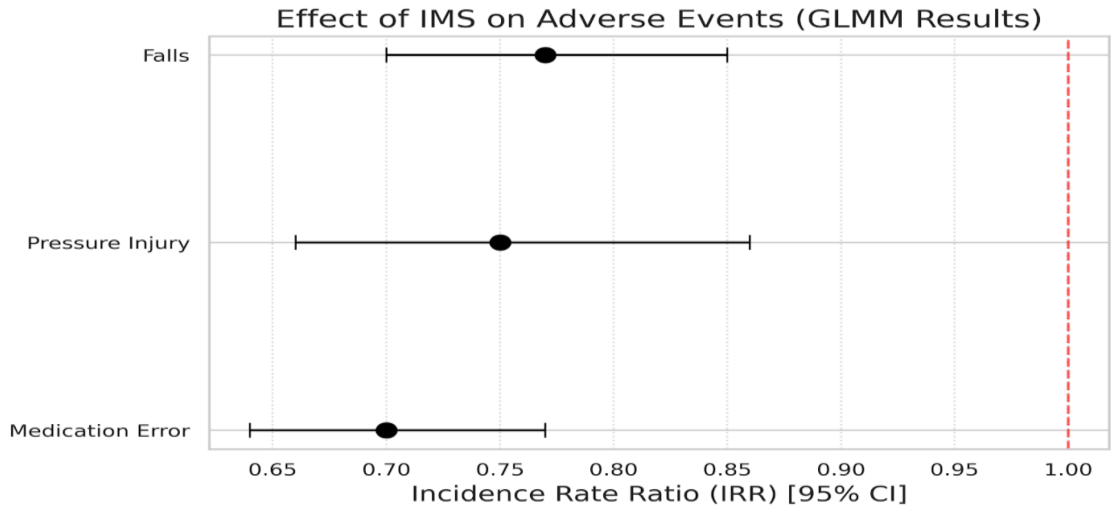

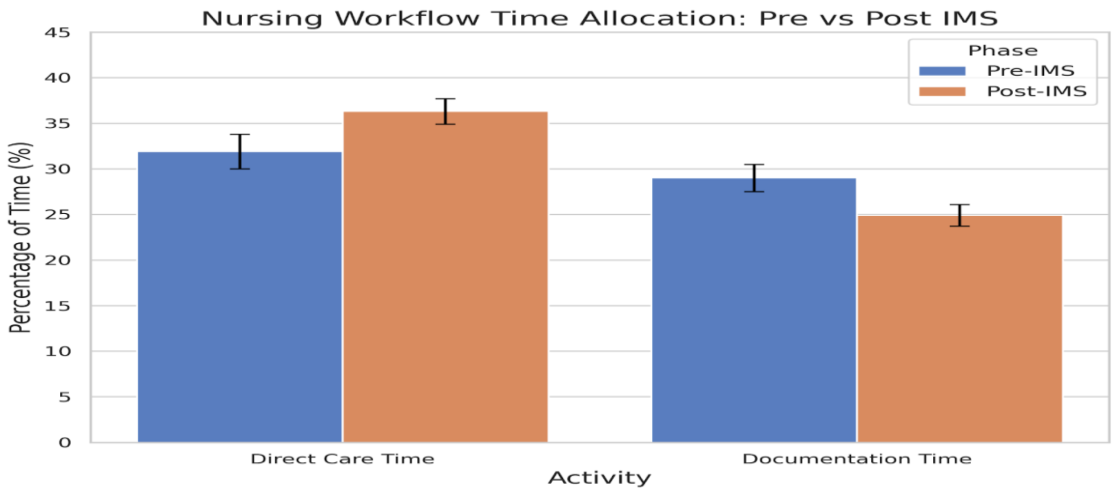

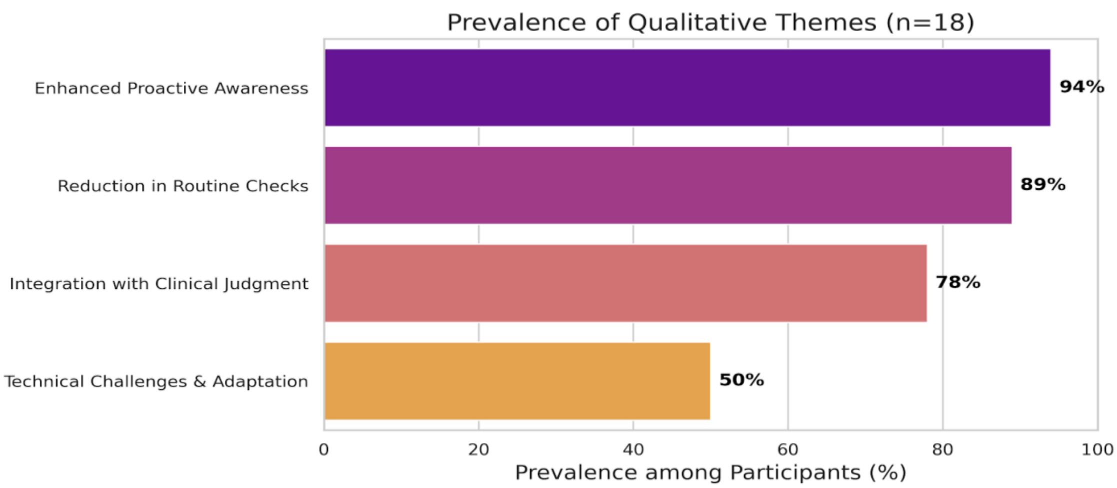

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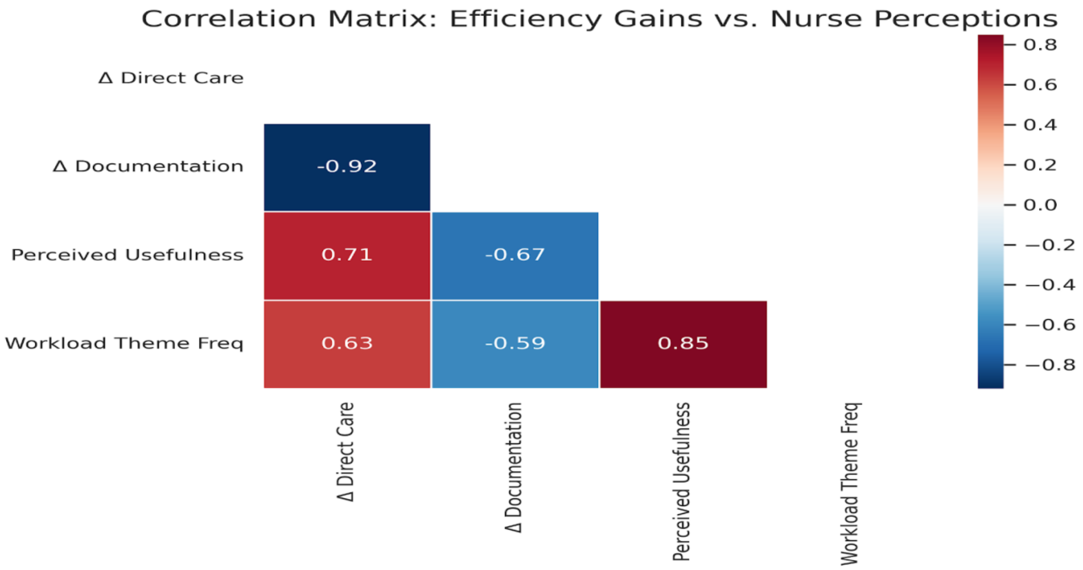

DISCUSSION

The findings of this study provide a robust, multi-faceted confirmation that the integration of an Intelligent Monitoring System (IMS) into inpatient nursing care within a Saudi Arabian tertiary hospital was associated with significant and desirable changes across three core domains: objective patient outcomes, nursing workflow efficiency, and staff perception [17]. This discussion interprets these interconnected results, contextualizes them within the broader scientific literature, explores the mechanistic explanations for the observed effects, considers their practical implications, and acknowledges the study's limitations.

1. Interpretation of Findings and Achievement

The primary objective of this research was to assess the impact of an IMS on the quality of nursing care. The data reveal a clear and positive effect. The significant reductions in rates of patient falls (23%), pressure injuries (25%), and medication administration errors (30%) are not merely statistical artifacts but represent clinically meaningful improvements in patient safety [18]. These metrics are internationally recognized as nursing-sensitive indicators, directly reflecting the quality and vigilance of care provided. The simultaneous, significant reallocation of nursing time—a 4.4% increase in direct care and a 4.1% decrease in documentation—directly addresses the second objective concerning workflow efficiency [19]. Crucially, this is not an increase in total workload but a strategic redistribution, shifting human resources from passive, administrative tasks toward active, patient-centered engagement.

The third objective, exploring nurse perceptions, yielded findings that powerfully explain and reinforce the quantitative data [20]. The dominant themes of Enhanced Proactive Awareness and Reduction in Routine Checks Burden provide the "how" behind the "what."

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Nurses reported that the IMS functioned as a continuous, automated sentinel, delivering predictive alerts that enabled earlier, more precise interventions—directly explaining the reduction in adverse events [21]. The alleviation of the manual surveillance burden logically accounts for the recovered time, which was then reinvested into direct care activities. The strong positive correlations between individual nurses' objective gains in direct care time and their subjective scores for perceived usefulness and reports of workload reduction provide compelling evidence of data triangulation [22]. This convergence from different methodological angles strengthens the validity of the conclusion that the IMS effected a tangible and positively perceived transformation in clinical practice.

2. Comparison with Previous Studies

Our findings align with and extend a growing body of international literature on digital health interventions in nursing. The reduction in patient falls corroborates earlier studies on bed-exit alarm systems, though our IMS, with its predictive analytics, represents an advancement over simple movement-activated alarms [23]. The observed decrease in pressure injury rates supports research on sensor-based monitoring for patient repositioning, such as the work by [24], who demonstrated similar efficacy with wearable devices. Our study contributes by integrating this functionality into a broader, non-contact monitoring platform.

Regarding workflow, our observation of reduced documentation time echoes findings from evaluations of Electronic Health Records (EHRs) with clinical decision support, where automation of data entry and vital sign integration saves time [25]. However, a critical distinction of our results is the clear endpoint for that saved time: an increase in direct patient care. This addresses a common concern in health informatics that technology often merely shifts, rather than reduces, workload [26]. The qualitative theme of Integration with Clinical Judgment is particularly significant. It contrasts with older, pessimistic views that cast technology as a de-skilling force. Instead, our nurses described a synergistic relationship, consistent with more contemporary frameworks like the "augmented intelligence" model in healthcare, where technology supports, rather than replaces, human expertise [27]. This finding aligns with the conclusions of [28], who argued that effective clinical alerts must inform, not interrupt, the nurse's cognitive workflow.

3. Scientific and Mechanistic Explanation

The biological and cognitive mechanisms underlying these results can be explained through the lens of human factors engineering and cognitive load theory. Traditional nursing monitoring is intermittent, episodic, and reliant on human memory and vigilance—a system vulnerable to attentional lapses, especially in high-workload environments [30]. The IMS introduces a layer of continuous, parallel processing. Physiologically, the system's sensors (e.g., depth sensors, thermal imaging) can detect subtle, pre-symptomatic changes—micro-movements preceding a

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fall attempt, prolonged pressure on a specific anatomical site, or irregular respiratory patterns—that are often imperceptible during brief manual checks [31].

Cognitively, the IMS reduces the "ambient monitoring" burden on the nurse's working memory. Automating the surveillance of routine parameters frees up cognitive resources [32]. This reduced cognitive load allows nurses to engage in higher-order clinical reasoning—the Integration with Clinical Judgment theme—when an alert is generated [33]. Instead of constantly scanning for basic stability, they can focus on interpreting complex situations, educating patients, and providing psychosocial support (the increased direct care). This shift from a proactive-preemptive model (constant checking) to a proactive-responsive model (alert-then-act) is more efficient and less mentally taxing [34]. The reduction in medication errors can be mechanistically linked to this same principle: with fewer cognitive resources devoted to basic monitoring, more are available for the meticulous, error-prone processes of medication verification and administration [35].

4. Implications for Practice, Policy, and Research

The implications of this study are substantial for hospital administrators, nursing leaders, and health policymakers in Saudi Arabia and similar contexts. Practically, the results provide a strong evidence-based rationale for the capital investment in IMS technology [36]. The demonstrated improvements in patient safety directly align with national healthcare quality goals and can potentially reduce the significant costs associated with hospital-acquired complications [37]. For nursing management, the workflow data offer a powerful tool for redesigning care models, demonstrating how technology can be leveraged to maximize the time nurses spend on tasks that require human compassion and expertise [38].

From a policy perspective, this research supports the broader vision of Saudi Vision 2030 for a technologically advanced healthcare sector. It provides a successful, locally validated case study for scaling smart hospital initiatives. Future research should build upon these findings [39]. Longitudinal studies are needed to determine if the observed benefits are sustained over the years and to conduct a formal cost-benefit analysis. Research must also explore the implementation of IMS in different settings, such as intensive care units, pediatric wards, or rural hospitals with different staffing models, to develop context-specific adaptation frameworks [40]. Furthermore, investigating the impact on other outcomes, such as nurse burnout, job satisfaction, and patient experience metrics, would provide a more holistic understanding of the technology's impact.

5. Limitations

While the study employed a robust mixed-methods design, certain limitations must be acknowledged. The use of a quasi-experimental pre-post design within a single hospital, though methodologically sound for this context, limits the generalizability of the findings. The absence

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of a concurrent control group from a different facility means we cannot definitively rule out the influence of other concurrent hospital-wide initiatives or secular trends on the outcomes. The time-motion observations, while conducted with high inter-rater reliability, may have been susceptible to the Hawthorne effect, where nurses modified their behavior because they were being observed. Finally, the study was conducted in a large, resource-rich tertiary center in Riyadh; the results may not be fully transferable to smaller or less-resourced hospitals without considering adaptations to the technology or its implementation strategy. These limitations, however, do not negate the strong, triangulated evidence of benefit but rather define the boundaries within which the conclusions are most confidently held and point the way for necessary future research.

CONCLUSION

This study demonstrated that the implementation of an Intelligent Monitoring System (IMS) in a Saudi Arabian hospital setting successfully improved nursing care quality and efficiency. The results confirmed that the IMS was associated with statistically significant reductions in patient falls, pressure injuries, and medication errors. Concurrently, nursing workflow was enhanced, with a measurable reallocation of time from documentation to direct patient care. Nurse perceptions strongly supported these quantitative findings, describing the system as a tool that enabled proactive care and reduced the burden of routine checks. The research met its objectives, providing empirical evidence that such technology can address critical patient safety and workflow challenges. The primary scientific contribution is a validated, multi-method model for evaluating clinical technology impact, specific to the Gulf region. In conclusion, intelligent monitoring represents a viable strategy for healthcare modernization. Future research should focus on long-term cost-benefit analyses and the adaptation of these systems for diverse clinical specialties and smaller healthcare facilities.

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