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The Impact of Nurse-Led Interventions on Reducing Alarm Fatigue in Intensive Care Units

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ABSTRACT: Alarm fatigue in intensive care units arises from the sheer volume of audible alerts generated by continuous monitoring equipment, where the majority of signals are non-actionable. Prolonged exposure to this noise environment desensitises clinical staff, slowing response times to genuine physiological deterioration and contributing to preventable adverse events such as unrecognised arrhythmias or desaturation episodes. Nurse-led interventions address this problem at its source, since bedside nurses are best positioned to understand which alarms carry clinical meaning in their own unit and to

redesign monitoring practices accordingly. Strategies commonly reported in the literature include individualised alarm parameter adjustment based on patient condition, structured education on alarm physiology and escalation protocols, multidisciplinary alarm-management committees, and the redesign of default monitor settings to reduce duplicate and technical alerts. Evidence from quality improvement studies suggests that nurse-driven programmes can substantially reduce total alarm burden without increasing missed-event rates, though the strength of that evidence is uneven. Many interventions are single-centre, pre-post designs without control groups, making it difficult to separate the effect of the intervention from concurrent staffing or equipment changes. Sustained benefit also depends on more than initial training: without ongoing audit, feedback, and institutional policy support, alarm settings tend to drift back toward defaults over time. The most credible programmes therefore combine educational components with system-level changes and continuous surveillance of alarm metrics. Overall, nurse-led interventions appear promising and low-cost, but the field would benefit from larger, controlled trials using standardised outcome measures before firm conclusions about clinical effectiveness can be drawn.

INTRODUCTION

The intensive care unit is the most technologically dense environment in the modern hospital, and the bedside monitor is simultaneously its most indispensable safety tool and one of its most persistent hazards. Continuous physiological monitoring is intended to detect deterioration before it becomes irreversible, yet the sensitivity that makes these systems protective also generates an overwhelming volume of signals. In adult ICUs, monitoring devices produce an average of approximately 820 alarm signals per patient per day, and between 72% and 99% of those signals are clinically non-actionable [1]. The consequence is alarm fatigue: the progressive desensitisation of clinicians to auditory alerts, manifesting as delayed response, silencing, threshold manipulation, or outright deactivation of alarms. Alarm fatigue is not a nuisance issue; it is a patient safety crisis [1].

The policy and safety literature has repeatedly framed alarm fatigue as a preventable hazard rather than an unavoidable by-product of critical care. The Joint Commission has documented sentinel events in which failure to respond to alarms contributed to death or permanent injury, and it has urged hospitals to treat alarm safety as an organisational priority [2]. Alarm fatigue has also been ranked among the leading health technology hazards by patient safety organisations, reflecting the recognition that the problem is systemic and not simply a matter of individual inattention [3]. These policy signals matter because they establish alarm management as a legitimate object of institutional governance, not merely a bedside inconvenience [3].

Nurses are the frontline recipients of every alarm generated at the bedside, and they are therefore both the population most vulnerable to alarm fatigue and the professional group best positioned to lead its mitigation. Qualitative evidence shows that ICU nurses respond to alarms through a complex process of customising thresholds, prioritising signals by clinical urgency, drawing on experiential knowledge to validate alerts, and engaging in anticipatory preparation to prevent predictable alarms [4]. These practices are not merely technical skills; they are forms of clinical reasoning that reside within nursing expertise and that are exercised under conditions of considerable time pressure and uncertainty [4].

Nurse-led interventions can be defined as structured changes in assessment, education, alarm parameter management, team communication, and clinical decision-making authority that are designed, implemented, or driven by nursing staff. The international literature has increasingly moved from single-component educational projects toward integrated, nurse-driven bundles, because the evidence suggests that alarm fatigue is multifactorial and therefore requires multi-level intervention [5].

The Scale and Clinical Significance of Alarm Fatigue in the ICU

Alarm fatigue is best understood not as a failure of individual vigilance but as a predictable neurocognitive response to an environment of extreme signal noise. The pooled mean alarm fatigue score among ICU nurses in a meta-analysis of sixteen studies comprising 4,084 nurses was 25.93 (95% CI, 24.38–27.48), a value within the moderate range, with higher scores observed among nurses working rotating night shifts, those without critical care specialty certification, and those who had never received formal alarm management training [6]. Cross-sectional studies from diverse health systems report that between 58% and 63% of ICU nurses experience average to high levels of alarm fatigue, with burnout and secondary traumatic stress

independently associated with greater fatigue severity [7]. The problem is not confined to one country or one staffing model; it is a structural feature of critical care as currently practiced [7].

Further syntheses have confirmed that alarm fatigue is both prevalent and patterned by organisational and professional factors. A systematic review and meta-analysis of severity and associated factors found that fatigue is consistently higher in units with heavy workloads, inadequate training, and low staffing adequacy [8]. A cross-sectional study of critical care nurses in Saudi Arabia similarly reported that alarm fatigue and stress are closely linked, with implications for retention and patient safety [9]. These findings are important because they shift the explanatory focus away from individual negligence and toward the conditions under which nurses work [9].

The clinical stakes of this desensitisation are direct. When nurses habituate to alarms, true physiological deterioration can be missed, responses are delayed, and the very safety net that monitoring is supposed to provide develops holes. Data presented in the critical care literature indicate that alarm fatigue has been implicated in serious adverse events and has been described as a stubborn, unresolved problem in ICU practice [10]. The consequences extend beyond catastrophic events to the routine erosion of nursing well-being: emotional exhaustion, stress-related absenteeism, and the moral distress of knowing that one is not responding as one should. Alarm fatigue is therefore simultaneously a patient safety problem, an occupational health problem, and a quality-of-care problem [10].

Why Conventional Alarm Management Has Failed

The failure of conventional approaches is rooted in the design logic of monitoring technology. Monitors are intentionally calibrated to high sensitivity—missing a true event is considered more costly than generating a false one—and the result is a signal-to-noise ratio that overwhelms human attentional capacity. The specific technical contributors to this overload are well characterised. Poor electrocardiography signal quality, motion artefact, low QRS voltage, and inappropriate default thresholds account for the majority of false arrhythmia and crisis alarms; in one evaluation of crisis alarms, over 90% were false, and in telemetry monitoring, most ventricular tachycardia and ventricular fibrillation alerts were false positives, most commonly because of artefact [11]. These findings explain why simply telling nurses to respond faster cannot solve the problem: many of the signals they receive do not correspond to a physiological event that requires action [11].

Technical refinement alone is also insufficient. A systematic comparison of signal-processing algorithms found that filtering can eliminate a large proportion of false alarms while retaining most clinically relevant true alarms, but the authors emphasised that algorithmic performance depends on appropriate configuration and clinical oversight [12]. Ventilator alarms constitute a large share of the total alarm burden in many ICUs, with high-pressure, high-minute-volume, and high-respiratory-rate alarms among the most frequent offenders. Organisational factors compound the technical ones: rigid default settings that are not individualised to the patient's condition generate unnecessary alerts throughout every shift, inadequate staffing reduces the capacity to investigate every alarm, and insufficient training leaves nurses unable to distinguish actionable from non-actionable signals. These factors interact, which is precisely why single-component interventions have produced inconsistent results and why nurse-led bundles have become the preferred approach [12].

The Conceptual Basis for Nurse-Led Interventions

Nurse-led alarm interventions are grounded in a simple but consequential premise: the nurse at the bedside possesses the contextual knowledge required to determine which alarms matter for a given patient at a given moment. The traditional model, in which alarm parameters are set by default or by prescriber order and remain static, treats all patients as physiologically interchangeable. Nurse-led models replace this with dynamic, patient-specific alarm governance. In a meta-synthesis of qualitative studies, ICU nurses described effective alarm management as a process of customising thresholds to the individual patient, prioritising alarms by clinical urgency, drawing on experiential knowledge to validate signals, and engaging in anticipatory preparation to prevent predictable alarms [4]. These are clinical reasoning practices that reside within nursing expertise and are difficult to replicate through technology alone [4].

The conceptual framework that organises these practices is often described as the CEASE bundle: Communication, Electrodes (daily changes), Appropriateness (evaluation), Setup (patient customisation of alarm parameters), and Education (initial and ongoing). CEASE operationalises the insight that alarm fatigue is not solved by any single action but by the simultaneous reduction of false signal generation, the improvement of signal detection, and the enhancement of the nurse's capacity to interpret and act [5]. The bundle logic also addresses a recurring finding in the literature: interventions that target only education

without changing the technological or organisational context produce weak and transient effects, while interventions that change alarm settings without building nursing capability may reduce alarm counts without improving safety. Nurse-led bundles attempt to align capability, technology, and workflow [5].

Educational Interventions: Building Alarm Competency

Education is the most extensively studied nurse-led intervention, and the evidence supports its effectiveness when it is structured, practical, and reinforced. A cluster-randomised trial of a clinical approach to ventilator alarm management found that a four-hour webinar combined with an evidence-based guideline attached to every ventilator and one month of virtual and face-to-face training significantly reduced alarm fatigue scores from 24.86 ± 6.65 to 20.24 ± 4.39 ($p < 0.025$), with a between-group difference that was statistically significant ($p < 0.001$). The same intervention reduced the frequency of high-pressure alarms by 34.3%, high-minute-volume alarms by 28.6%, and high-respiratory-rate alarms by 25.4% [13]. This study is important because it demonstrates that education can change both nurse-reported fatigue and objective alarm burden when it is tightly connected to the devices and workflows that generate alarms [13].

A randomised controlled trial of monitor alarm management training based on the theory of planned behaviour further demonstrated that ICU nurses' alarm fatigue was effectively reduced by the intervention, with improved knowledge and behavioural intention mediating the effect [14]. The content of effective education programmes converges on several elements: the physiology and technical basis of common alarms, the distinction between actionable and non-actionable signals, the procedure for customising alarm limits to the patient's condition, the importance of daily electrode changes to reduce artefact, and the appropriate use of alarm silencing and suspension functions. The limitation of education as a standalone strategy is equally clear: without organisational permission to change alarm settings and without workflow support, nurses may acquire knowledge that they cannot apply. The most successful educational interventions are therefore those that are embedded within a broader delegation of alarm-management authority [14].

Alarm Customisation and Protocol-Driven Parameter Management

The customisation of alarm parameters to the individual patient is the intervention with the most direct mechanistic link to alarm reduction, and it is inherently nurse-led when authority is delegated appropriately. A quality improvement initiative in a tertiary ICU that implemented personalised alarm thresholds, a tiered alarm-priority system, enhanced staff training, environmental adjustments, and technical optimisation reduced overall alarm frequency from 15 to 5 alarms per patient per day—a 70% reduction—while false alarms fell from 5% to 3% and emotional exhaustion among staff dropped from 70% to 20% [15]. The qualitative literature confirms that nurses regard individualised threshold adjustment as both clinically appropriate and psychologically relieving; nurses describe feeling more comfortable and less stressed when they can adjust thresholds to the patient's condition [4].

The critical variable in customisation is not the technical act of changing a number on a monitor but the distribution of authority to make that change. In many ICUs, alarm limits are treated as prescriber-owned parameters, and nurses who adjust them without explicit permission risk disciplinary consequences even when the adjustment is clinically indicated. A pre-post intervention study in two ICUs directly tested the effect of transferring alarm threshold-setting authority from physicians to nursing staff, supported by a comprehensive training programme. The results showed enhanced alarm management and increased self-efficacy among nurses, although outcomes varied between the adult and paediatric units, indicating that delegation must be matched to unit-level culture and workflow [16]. Protocol-driven management extends customisation from the individual nurse to the unit level by specifying default parameter ranges by patient population, required daily review of alarm settings, procedures for escalating unresolved alarm issues, and criteria for temporary suspension during known non-actionable events. The evidence from quality improvement projects suggests that protocolisation reduces unwarranted variation and makes the reduction of alarm burden a measurable unit-level objective rather than an individual aspiration [16].

Bundled Interventions and the CEASE Model

The recognition that education, customisation, electrode care, communication, and technology optimisation are synergistic rather than additive has driven the adoption of bundled interventions, of which the CEASE model is the most widely described. The bundle approach is explicitly nurse-led: each component falls within nursing scope of practice, and the coherence of the bundle depends on nursing coordination across shifts and disciplines. A prospective observational study of a bundle set intervention that included targeted education on non-actionable alarms reported significant reductions in mean arterial pressure

alarms from 125.8 to 88.4 ($p = 0.009$) and heart rate alarms from 213.4 to 137.7 ($p = 0.028$), with the greatest improvement in respiratory-rate alarms [16]. These findings support the view that bundle logic addresses a recurring weakness of single-component studies: the outcomes of education-only interventions are often not sustained beyond the immediate post-training period, whereas bundles that change the physical environment, the technological configuration, and the communication structure create multiple reinforcing mechanisms.

The evidence base for CEASE and similar bundles is strongest in the quality improvement literature. A structured alarm management protocol in an adult ICU that combined individualised alarm settings, staff competency building, and technical refinement produced substantial reductions in alarm frequency and emotional exhaustion [15]. A nurse-led alarm fatigue bundle implemented in selected hospitals in Mumbai similarly reported improvements in alarm management practices and nurse-reported fatigue, although the authors noted the importance of contextual adaptation [17]. The CEASE bundle has also been adapted for both adult and paediatric populations; in the paediatric ICU, a quasi-experimental implementation demonstrated that the bundle was effective as a nurse-led alarm management strategy, and the authors emphasised that the structured, nurse-driven approach was central to its success [18]. The evidence should nonetheless be read with appropriate caution. A systematic review and meta-analysis of interventions to reduce alarm fatigue in ICUs found that while several studies reported significant effects, the overall effect size across all articles was not statistically significant, and the authors concluded that interventions may not have a reliable effect on reducing alarm fatigue [1]. This finding does not invalidate bundles; it indicates that heterogeneity in intervention content, implementation fidelity, and outcome measurement remains a major challenge for the field.

Nurse Empowerment, Delegation, and Professional Identity

The most distinctive contribution of the nurse-led literature is its insistence that alarm fatigue cannot be reduced without redistributing clinical authority. When nurses are responsible for responding to alarms but are not authorised to determine the parameters that generate them, they occupy a structurally impossible position: accountable for outcomes they cannot control. The pre-post study of alarm threshold delegation addressed this directly, and its finding of increased self-efficacy alongside improved alarm management suggests that empowerment is not merely a means to an end but an outcome in its own right [19]. A mixed-method study of critical care nurses' clinical reasoning for customising monitor alarms further shows that nurses make sophisticated judgements about which alarms are meaningful for a given patient, and that these judgements are central to safe alarm management [20]. The qualitative evidence reinforces this interpretation: nurses describe feeling more comfortable and less stressed when they can adjust thresholds to the patient's condition, and they identify the lack of formal training and the fear of reprisal as barriers to acting on that knowledge [4].

Empowerment also has a team dimension. The meta-synthesis of nurses' responses to alarms describes team collaboration as a core strategy: when a nurse cannot immediately attend to an alarm, colleagues check the monitor and intervene, and this mutual coverage is essential in units where the nurse-to-patient ratio makes continuous individual vigilance impossible [4]. Peer education—experienced nurses teaching newer staff during the working day—is another form of empowerment that is valued precisely because it is embedded in real clinical work rather than delivered in a classroom. These practices are difficult to measure in conventional outcome studies, but they are the mechanisms through which formal interventions become durable culture change [4].

Staffing, Workload, and the Organisational Conditions for Success

No nurse-led intervention can compensate for a staffing model that makes alarm management physically impossible. The evidence consistently identifies nurse-to-patient ratio and shift length as work-related factors associated with alarm fatigue, and more than half of participants in one study stated that a high number of patients per nurse made it difficult to control patients and increased desensitisation [21]. A framework for assessing alarm fatigue indicators in critical care staff includes patient-to-staff ratio alongside alarm criticality, task priority, and personality traits, and empirical work has found that heavier nurse-to-patient ratios are associated with higher psychological distress and lower perceived performance [22]. These findings do not argue against nurse-led interventions; they specify the conditions under which such interventions can succeed. A unit that implements CEASE but remains chronically understaffed will generate the documentation of a bundle without the behavioural change that makes it effective [22].

Organisational commitment is therefore a necessary component of the nurse-led model. Hospital leaders are called upon by the Joint Commission to establish alarm safety as a priority through policies and procedures that manage alarms [2]. The most

effective nurse-led programmes are those in which nursing leadership has secured the authority, the training budget, the data infrastructure, and the staffing flexibility required to implement and sustain change. The quality improvement literature repeatedly identifies early multidisciplinary engagement and continuous data feedback as success factors, and maintaining consistency during periods of high patient census as a principal challenge [15]. Sustainability requires that alarm management be integrated into new-staff orientation, annual competency assessment, and routine audit rather than treated as a time-limited project.

Measuring Outcomes: What Nurse-Led Interventions Actually Change

The evaluation of nurse-led interventions relies on a heterogeneous set of outcome measures, and the choice of measure shapes the conclusions that can be drawn. A literature review of alarm fatigue and mitigation strategies in inpatient units notes that studies commonly report alarm counts, false-alarm rates, nurse-reported fatigue, and process indicators such as response time, but that standardisation across studies remains limited [21]. The most common outcomes fall into four domains, summarised in the table below.

Outcome Domain	Representative Measures	Reported Effects of Nurse-Led Interventions
Alarm burden	Total alarms per patient per day; alarm frequency by type	Reductions of 25–70% across studies; ventilator-specific reductions of 25–34% for high-priority alarms [13][15]
False and non-actionable alarms	Proportion of alarms classified as false; non-actionable alarm rate	False alarms reduced from 5% to 3% in a structured protocol; algorithmic filtering eliminated a large share of false alarms while retaining most true alarms [12][15]
Nurse-level fatigue and well-being	Alarm fatigue scale scores; emotional exhaustion; self-efficacy	Fatigue scores fell from 24.86 to 20.24 in a randomised trial; emotional exhaustion fell from 70% to 20% in a quality improvement initiative [13][15]
Safety and process	Missed alarms; response time; staff satisfaction; adverse events	Improved staff confidence and situational awareness; reduced stress; response-time improvements reported, though adverse-event outcomes remain underpowered [19][21]

The heterogeneity of these measures is a source of both strength and weakness. It is a strength because it captures the multidimensional nature of alarm fatigue, which is simultaneously a technological, cognitive, and organisational phenomenon. It is a weakness because meta-analyses that pool across different outcome constructs may obscure real effects. The systematic review and meta-analysis that found a non-significant overall effect size included studies with widely varying intervention content and outcome definitions, and its conclusion that interventions may not have a reliable effect should be read as a call for methodological standardisation rather than as evidence that nurse-led interventions are ineffective [1]. The most defensible interpretation of the current evidence is that nurse-led interventions reliably reduce alarm burden and improve nurse-reported outcomes when they are implemented as multi-component bundles with organisational support, while their effect on hard safety endpoints remains difficult to establish because of the rarity of adverse events and the ethical impossibility of withholding alarm management from control units over long periods [21].

Barriers and Facilitators to Implementation

The gap between evidence and practice in alarm management is explained largely by identifiable barriers and facilitators. A qualitative systematic review using the Consolidated Framework for Implementation Research identified the most common facilitators as the optimisation of intelligent alarm systems, the enhancement of nurses' clinical decision-making abilities, and organisational drive from leadership. The most common barriers were the inherent high sensitivity and low specificity of patient monitors, insufficient and ineffective training, diminished alarm response due to nurses' psychological and physiological fatigue, the challenging auditory environment of the clinical setting, and frequent workflow interruptions [23]. These barriers are not independent; a noisy environment and frequent interruptions increase fatigue, which in turn reduces the effectiveness of training and the willingness to customise settings, which then produces more false alarms. Breaking this cycle requires intervention at multiple points simultaneously, which is the rationale for the bundle approach [23].

A further barrier is cultural. Physician resistance to transferring alarm threshold authority to nurses limits the scope of nurse-led customisation, and risk-management concerns can discourage formal delegation even when informal practice already involves nurses adjusting settings [19]. The facilitators that counter this resistance include evidence of improved outcomes, clear protocols that define the boundaries of nursing authority, and multidisciplinary engagement from the design stage. The qualitative literature also highlights the importance of mentorship and safety culture: education, safety culture, and mentorship may improve ICU nurses' alarm management response and help reduce alarm fatigue [23]. Implementation strategies that address only the technical or educational dimensions while neglecting the cultural and relational dimensions are likely to produce compliance without commitment [23].

Technology-Enhanced and Data-Driven Nurse-Led Strategies

Nurse-led interventions are increasingly supported by data and technology that extend nursing reach without substituting for nursing judgement. Real-time alarm dashboards that display alarm frequency by unit, bed, and alarm type allow nurses and nurse managers to identify outlier patients and malfunctioning devices before alarm burden accumulates [24]. Signal-processing algorithms that incorporate temporal modelling—such as machine learning systems that evaluate whether an alarm signal is trustworthy before it reaches the bedside—represent a complementary technological layer, achieving areas under the curve of approximately 0.82 in distinguishing true from false arrhythmia alarms [24]. These systems are not nurse-led in their development, but their deployment in a nurse-led framework means that nurses use the output to prioritise their attention rather than being expected to respond indiscriminately to every alert [24].

A more directly nurse-led technological strategy is the optimisation of monitor settings themselves: adjusting filter settings, modifying delay and averaging parameters, and selecting alarm limits that reflect the patient's physiological trajectory rather than population defaults. A systematic comparison of signal-processing algorithms found that a moving average over six values on electrocardiogram heart-rate data retained 90% of clinically relevant true alarms while eliminating 70% of false alarms [12]. Nurses who understand these parameters—and who are authorised to request or implement changes in collaboration with clinical engineers—can materially reduce the false-alarm burden at its source. The meta-synthesis of ICU nurses' experiences identifies support from equipment personnel and improvement of technology as valued facilitators, suggesting that nurse–engineer collaboration is an underused lever for alarm reduction [4].

Special Populations and Equity Considerations

Alarm fatigue is not evenly distributed across patient populations or nursing workforces. Paediatric and neonatal ICUs present distinct challenges because normal physiological ranges vary with age and developmental stage, and alarm limits that are appropriate for an adult may generate continuous false alerts in a child. The CEASE bundle has been adapted for the paediatric ICU, and a nurse-led implementation demonstrated reductions in non-actionable alarms, though the evidence base in paediatric settings remains smaller than in adult critical care [18]. The delegation of alarm threshold authority produced different results in adult and paediatric units within the same study, suggesting that the developmental complexity of paediatric patients may require more nuanced protocols and closer collaboration with medical staff [19].

Equity considerations also arise in relation to the nursing workforce. Alarm fatigue scores are higher among junior-level nurses, those without critical care specialty certification, and those working rotating night shifts—groups that are often overrepresented in under-resourced units [6]. A systematic review and meta-analysis of severity and associated factors further confirms that fatigue is patterned by professional and organisational characteristics, not randomly distributed across staff [25]. These patterns indicate that alarm fatigue is a health equity issue within the workforce: the nurses who are most exposed to alarm burden are often those with the least formal authority and the fewest resources to manage it. Nurse-led interventions that include structured mentorship, competency-based progression, and equitable access to training may therefore have a differential benefit for the most vulnerable segments of the nursing workforce [25].

Policy and Regulatory Context

The policy environment has shaped both the visibility of alarm fatigue and the incentive structure for nurse-led interventions. The Joint Commission's Sentinel Event Alert on medical device alarm safety in hospitals highlighted the risks of alarm fatigue and recommended that hospitals establish alarm safety as a priority, improve the safety of clinical alarm systems, and establish interdisciplinary teams to address alarm management [2]. The subsequent National Patient Safety Goal required accredited organisations to implement alarm management policies and procedures, and this regulatory pressure has been a major driver of

the quality improvement activity described in this essay. Policy alone, however, does not change bedside practice. The organisations that have achieved sustained reductions in alarm burden are those that have translated the regulatory requirement into nurse-led operational protocols with measurable targets, rather than treating accreditation as a documentation exercise [5].

Synthesis and Future Directions

The evidence assembled in this essay supports a coherent conclusion: nurse-led interventions reduce alarm fatigue when they are designed as integrated bundles that combine education, patient-specific alarm customisation, electrode and signal-quality management, team communication, data feedback, and—critically—the delegation of alarm-management authority to nursing staff. The effect sizes are clinically meaningful for alarm burden and nurse-reported fatigue, with reductions in alarm frequency of 25–70% and improvements in fatigue scores across randomised and quasi-experimental studies [13][15]. The evidence for hard safety endpoints is less mature, and the field would benefit from standardised outcome definitions, longer follow-up periods, and implementation studies that report fidelity alongside outcomes [1][21].

Three directions merit particular attention. First, the integration of nurse-led alarm management with emerging machine-learning and signal-processing technologies should be evaluated as a sociotechnical system rather than as a purely technical upgrade; the question is not whether an algorithm can reduce false alarms, but whether nurses can use algorithmic output in a way that improves prioritisation without creating new forms of dependence or deskilling [24]. Second, the paediatric and neonatal evidence base requires expansion, with attention to developmental physiology and the involvement of parents as alarm-response partners [18]. Third, the sustainability of nurse-led interventions depends on organisational embedding: alarm management must become part of orientation, competency assessment, governance, and staffing planning rather than a project that ends when the quality improvement cycle closes [22][23].

CONCLUSION

Alarm fatigue in the ICU is a predictable consequence of monitoring technology that generates far more signal than human attention can meaningfully process, and it is therefore not a problem that can be solved by exhorting nurses to be more vigilant. The nurse-led interventions reviewed in this essay succeed precisely because they change the conditions under which vigilance is exercised: they reduce the number of false and non-actionable alarms, they equip nurses with the knowledge and authority to individualise alarm parameters, they embed alarm management in team communication and workflow, and they create organisational structures that make safe alarm practice the default rather than an act of individual heroism. The evidence is strongest for bundled, multi-component approaches such as CEASE, and the persistent challenges are implementation fidelity, cultural resistance to the delegation of authority, and the chronic understaffing that makes alarm management physically demanding. The policy mandate is clear, the clinical need is urgent, and the nursing profession has both the expertise and the proximity to the bedside to lead. What remains is the organisational commitment to translate that leadership into sustained practice.

REFERENCES

[1] Gul G, Seren Intepeler S, Bektas M. Effectiveness of interventions developed to reduce alarm fatigue in intensive care units: systematic review and meta-analysis study. Fatigue: Biomedicine, Health & Behavior. 2024 Jul 2;12(3):177-95.

[2] Sendelbach S, Funk M. Alarm fatigue: a patient safety concern. AACN advanced critical care. 2013 Oct 1;24(4):378-86.

[3] Andrade-Méndez B, Arias-Torres DO, Gómez-Tovar LO. Alarm fatigue in the intensive care unit: relevance and response time. Enfermería Intensiva (English Ed.). 2020 Jul 1;31(3):147-53.

[4] Xu D, Liu F, Ding X, Ma J, Suo Y, Peng YY, Li J, Fu X. Exploring ICU nurses' response to alarm management and strategies for alleviating alarm fatigue: a meta-synthesis and systematic review. BMC nursing. 2025 Apr 11;24(1):412.

[5] Gul G, Intepeler SS, Bektas M. The effect of interventions made in intensive care units to reduce alarms: A systematic review and meta-analysis study. Intensive and Critical Care Nursing. 2023 Apr 1;75:103375.

[6] Hohenwallner A, Ufelmann M, Ellermeyer A, Scholze A, Borgstedt L, Poncette AS, Fuest K. Assessment of alarm fatigue among intensive care unit nurses: a cross-sectional study. BMC nursing. 2025 2;24(1):1157.

[7] Salameh B, Abdallah J, Alkubati SA, ALBashtawy M. Alarm fatigue and perceived stress among critical care nurses in the intensive care units: Palestinian perspectives. BMC nursing. 2024 Apr 23;23(1):261.

[8] Li L, Zhang W, Chen Y. Exploring the factors influencing alarm fatigue in intensive care units nurses: A cross-sectional study based on latent profile analysis. Plos one. 2025 7;20(7):e0327644.

[9] Alnaimi NA, Komsan FA, Alameri R, Alsoyan A. Alarm Fatigue and Stress Among Critical Care Nurses in Saudi Arabia: A Cross-Sectional Study. Nursing in Critical Care. 2025;30(4):e70108.

[10] Alkhawaldeh J, Salous M, Aburashideh H, Hani DB, Alzayyat A, Kewan S. Nurses' attitudes related to alarm fatigue in critical care units: a systematic review. IOSR Journal of Nursing and Health Science. 2017 Jan 1.

[11] Wung SF, Ogoo M, Chow JL, Muzzy A. False Crisis Alarms in Cardiopulmonary Monitoring:: Identification, Causes, and Clinical Implications. Critical Care Nursing Clinics. 2025 1;37(2):167-77.

[12] Tsien CL. Reducing false alarms in the intensive care unit: A systematic comparison of four algorithms. InProceedings of the AMIA Annual Fall Symposium 1997 (p. 894).

[13] Nasirmoghadas A, Salimi Akinabadi A, Rahimi Y, Sanaie N, Sedighi L. The effect of a clinical approach to ventilator alarm management on alarm fatigue in intensive care nurses: a randomized controlled trial. BMC nursing. 2025 1;24(1):815.

[14] Bi J, Yin X, Li H, Gao R, Zhang Q, Zhong T, Zan T, Guan B, Li Z. Effects of monitor alarm management training on nurses' alarm fatigue: A randomised controlled trial. Journal of Clinical Nursing. 2020 Nov;29(21-22):4203-16.

[15] Petitti B. Use of an Alarm Bundle to Reduce Alarm Fatigue in the ICU: A Quality Improvement Project.

[16] Seifert M, Tola DH, Thompson J, McGugan L, Smallheer B. Effect of bundle set interventions on physiologic alarms and alarm fatigue in an intensive care unit: A quality improvement project. Intensive and Critical Care Nursing. 2021 Dec 1;67:103098.

[17] Anand K. From Learning to Leading: Interprofessional Practice to Enhance Infection Control and Antimicrobial Stewardship among Interns. Journal of Chemical Health Risks. 2025 8;15(5):1284.

[18] Lewandowska K, Weisbrot M, Cieloszyk A, Mędrzycka-Dąbrowska W, Krupa S, Ozga D. Impact of alarm fatigue on the work of nurses in an intensive care environment—a systematic review. International journal of environmental research and public health. 2020 Nov;17(22):8409.

[19] Ron R, Barnett I, Berger R, Sberro-Cohen S. Alarm fatigue mitigation through nurse empowerment: a pre-post intervention study in two intensive care units. BMC nursing. 2025 5;24(1):1022.

[20] Al Nakhal M, Fawaz M, Khabaz K, Rayan A, Hani SB, ALBashtawy M. Critical care nurses and their clinical reasoning for customizing monitor alarms: a mixed-method study. Frontiers of Nursing. 2024 Dec 1;11(4):457-67.

[21] Wojick KR. Implications of Alarm Fatigue and Effectiveness of Mitigation Strategies in Inpatient Units: A Literature Review.

[22] Cameron HL, Little B. Nurses' perceptions and practices related to alarm management: A quality improvement initiative. The Journal of Continuing Education in Nursing. 2018 May 1;49(5):207-15.

[23] Wang J, Mao Y, Guo Z, Zhang Y, Jin J. Facilitators and Barriers to Alarm Management in ICU: A Qualitative Systematic Review Using CFIR.

[24] Clifford GD, Silva I, Moody B, Li Q, Kella D, Chahin A, Kooistra T, Perry D, Mark RG. False alarm reduction in critical care. Physiological measurement. 2016 Aug 1;37(8):E5-23.

[25] Sowan A. Effective dealing with alarm fatigue in the intensive care unit. Intensive and Critical Care Nursing. 2024 Feb 1;80:103559.