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Clinical Alarm Awareness, Management Challenges, and Alarm Fatigue Among ICU Nurses

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Abstract

Background

Clinical alarms play a crucial role in ensuring patient safety in intensive care units (ICUs). However, excessive alarms and ineffective alarm management contribute to alarm fatigue among nurses, potentially compromising patient care.

Objective

This study aimed to evaluate ICU nurses' awareness of clinical alarm settings, response times, challenges associated with alarm management, and the prevalence of alarm fatigue.

Methods

A descriptive cross-sectional study was conducted among 60 ICU nurses at a tertiary care hospital. Data collection involved demographic profile, observational assessments of alarm awareness and response times, and self-report surveys addressing obstacles to alarm management and alarm fatigue. Statistical analysis was performed via SPSS version 21.

Results

The majority of participants (65%) were between 21 and 24 years old, with 83.3% being female. Awareness of patient monitoring and infusion pump alarms was universal (100%); however, 10% of nurses demonstrated insufficient knowledge of ventilator alarm settings. In terms of response times, 86.7% of the participants reported ventilator alarms within two minutes, whereas 83.3% responded to infusion pump alarms within the same timeframe. The most frequently cited obstacle to alarm management was inadequate staffing (55%), followed by frequent false alarms (20%) and difficulty identifying alarm sources (20%). Alarm fatigue was prevalent, with nurses reporting symptoms such as anxiety (70%), difficulty concentrating (65%), and headaches (58.3%).

Conclusion

Despite ICU nurses exhibiting high awareness of clinical alarms, concerns remain regarding delayed response times and the impact of alarm fatigue. Addressing staff shortages, implementing standardized alarm management protocols, and minimizing false alarms are essential to enhancing both patient safety and nurse well-being.

Introduction

Clinical alarms play crucial roles in patient monitoring and safety within intensive care units (ICUs). However, the increasing number of alarms has introduced new challenges, notably alarm fatigue, which impairs nurses’

responsiveness and poses risks to patient safety. Alarm fatigue is defined as the desensitization of healthcare workers due to excessive exposure to alarms, leading to delayed or missed responses (1) (2). This phenomenon has been recognized as a significant concern affecting both healthcare professionals and patient outcomes(3) (4). Modern ICU environments, equipped with multiple monitoring systems such as ventilators, infusion pumps, and patient monitors, generate numerous audible and visual alarms intended to alert healthcare staff to potential dangers. Studies indicate that nurses in ICUs encounter an average of 350 alarms per bed per day, with 85–99% being nonactionable, further exacerbating alarm fatigue (2) (3) to communicate with alien The high frequency of false alarms, poor alarm customization, and inadequate training contribute to alarm fatigue and stress among ICU nurses(5).

Alarm fatigue has been linked to adverse events, including patient harm and mortality. In 2013, the Joint Commission reported 98 alarm-related events, 80 of which resulted in deaths (6). Persistent exposure to alarms not only affects patient safety but also contributes to nurse burnout, increased stress levels, and reduced job satisfaction(7). Nurses experiencing alarm fatigue report symptoms such as trouble concentrating, heightened anxiety, and chronic fatigue (8),(9). Additionally, alarm fatigue can lead to suboptimal nursing practices, such as adjusting alarm parameters outside safe limits or disabling alarms altogether, which can compromise patient care (10).

Efforts to mitigate alarm fatigue have included alarm customization, interdisciplinary teamwork, and technological advancements in alarm systems. The implementation of intelligent alarm management strategies, such as integrating machine learning-based algorithms to filter nonessential alarms, has shown promise in reducing unnecessary alarm exposure(11). Moreover, structured training programs for ICU nurses on alarm settings and prioritization can enhance their ability to differentiate between clinically significant and nonactionable alarms(12).

Recognizing the urgency of this issue, the Joint Commission and other healthcare regulatory bodies have prioritized alarm management as a critical patient safety goal, which involves identifying the most important clinical alarms and establishing policies and procedures for the management of clinical alarms.(13) Hospitals worldwide are exploring solutions to improve alarm management protocols and enhance the working conditions of ICU nurses.

The primary objectives of this study were to assess ICU nurses' awareness of clinical alarm settings, identify and rank the obstacles they face in recognizing and responding to alarms, and evaluate the extent of alarm fatigue among ICU nurses.

By addressing these objectives, this study aims to provide actionable insights into improving alarm management protocols and reducing alarm fatigue. The findings will be beneficial for healthcare administrators, policymakers, and frontline nursing staff, enabling them to develop strategies that prioritize patient safety and enhance nurses' work efficiency.

Methods

A descriptive cross-sectional study was conducted at a tertiary care hospital. The study targeted ICU nurses working in the Medical Intensive Care Unit (MICU) and Critical Care Unit (CCU), where continuous monitoring is

critical. The target population comprised ICU nurses. The sample size calculated for the current study was based on a previous study(14). (14)There were 34 nurses in the MICU and 35 nurses in the CCU. athocal clearance for the study was obtained from the Institutional Ethics Committee (Ref: CSP/21/Sept/99/487). The study was conducted in full accordance with the ethical standards of the Institutional Ethics Committee and the principles outlined in the Declaration of Helsinki (2013 revision), ICMR guidelines on biomedical research in human beings and principles of Good clinical practice. The researcher explained the study's purpose, procedures, potential risks, and benefits to all participants. Written informed consent was obtained from each participant prior to data collection. Participants were assured of the confidentiality and anonymity of their responses, and their participation was entirely voluntary. All data were handled in compliance with applicable ethical guidelines to ensure the privacy and rights of the participants were protected throughout the study.

A purposive sampling technique was employed to select 60 participants with more than six months of experience.

Data were collected via a structured questionnaire and an observation sheet to ensure a comprehensive assessment of nurses' awareness, challenges in alarm management, and response to clinical alarms.

Research tools had five components the first three included background data of the nurses participating in the study, assessment of alarm awareness and an observation checklist of time taken to respond to the patient specific clinical alarms were developed by researchers on the basis of observations in intensive care units (ICUs). The assigned nurse was expected to know and correctly set the upper and lower limits for each alarm parameter. The alarm settings on the patient monitors included blood pressure (systolic and diastolic), heart rate, respiratory rate, and SpO_2. The mechanical ventilator settings used included the PEEP, FiO_2, tidal volume, and respiratory rate. Nurses were observed while setting the ventilator parameters during their shift, during procedures such as suctioning, and in response to alarms. Additionally, nurses' ability to recognize infusion pump alarms, whether due to near completion or interruptions such as occlusions, was assessed.

Alarm awareness for each nurse was scored on the basis of their ability to set and recognize alarms on monitors, ventilators, and infusion pumps. Observations of their responses to alarms were recorded via a checklist completed by another ICU nurse who was not involved in the research. This pilot study was conducted among 10 nurses in the surgical ICU. Alarm awareness was scored with a value of 1 for "aware" and 0 for "not aware."

The scales assessing obstacles to alarm management and alarm fatigue were adapted from a previous study with permission from the authors.(14) To establish the reliability of the instruments, a pilot study was conducted in the surgical ICU via the test–retest method. The reliability coefficient was found to be 0.86 for the obstacles to alarm management scale and 0.80 for the alarm fatigue scale, indicating strong consistency in the measurements.

An observation sheet was utilized to assess nurses’ response times and accuracy in NOT handling clinical alarms. Each nurse was observed for a minimum of two shifts while providing patient care to ensure an accurate representation of their alarm management practices.

Descriptive and inferential statistics were used to analyze the data. Ranking was applied to determine the most significant obstacles to effective alarm management. Statistical analysis was performed via SPSS version 21.

Results

Demographic profile of the participants

Table 1
Demographic characteristics of critical care nurses

Background Variables	(n = 60)	
	n	%
Age in year		
21–24	**39**	**65**
25–30	**10**	**16.7**
31–40	**11**	**18.3**
Gender		
Male	10	16.7
Female	50	83.3
Education		
Diploma	15	25
B.Sc	45	75
Designation		
Junior Nurse	28	46.7
Nurse	20	33.3
Senior Nurse	3	5
Shift In charge	9	15
Working experience		
Less then 1year	28	46.7
2–5 years	17	28.3
5- 10years	9	15
Above 10 years	6	10
Previous experience in alarm related research		
No	60	100
Yes	0	0

Table 1 highlights the demographic characteristics of the 60 participating ICU nurses. The study included 60 ICU nurses, with the majority (65%) aged 21–24 years. Female participants constituted 83.3%, whereas 75% held a B.Sc. Nursing degree. Most nurses (46.7%) had less than one year of experience, and none had previously participated in research related to clinical alarm management.

Awareness of clinical alarm settings

Table 2
Awareness of alarm settings among critical care nurses

Awareness of clinical alarm on	N = 60	%
Patient monitor		
Blood pressure	60	100
Systolic	60	100
Diastolic		
Heart rate	60	100
Respiration	60	100
Spo2	60	100
Setting	60	100
Mechanical ventilator		
Peep	60	100
Fio2	60	100
Respiration rate	60	100
Tidal volume	60	100
Setting		
Inadequate	6	10
Adequate	54	90
Infusion pump	60	100
Setting	60	100
Awareness	60	100

The assessment of nurses' awareness of the clinical alarm settings (Table 2) revealed that all participants (100%) were aware of the correct upper and lower limits for blood pressure (systolic and diastolic), heart rate, respiratory rate, and oxygen saturation. Awareness regarding mechanical ventilator settings was slightly lower,

with 90% demonstrating knowledge of parameters such as PEEP, FiO2, respiratory rate, and tidal volume. All the nurses were knowledgeable about the infusion pump settings.

Response time to clinical alarms

Table 3
Responses of critical care nurses to clinical alarms

Patient connected with	N = 60	%	False Alarm	Reasons
Mechanical Ventilator	52	86.7	0	• Presence of water in the ventilator circuit • Disconnected Mask • Assigned with two patients at the same time • Needed to load medication and prepare for enteral feeding
Delay by < 2 mins	8	13.3		
Delay > 2 mins to 5 mins	0	0		
Delay > 5 mins				
Infusion pump	50	83.3	0	• Medicine was over and had to reconnect and start the next syringe • A block in IV line and 100 cm extension, • IV line was removed and had to insert a new line • Air bubbles needed to be expelled from IV line
Delay by < 2 mins	10	16.7		
Daley > 2 mins to 5 mins	0	0		
Delay > 5 mins				
Patient monitors	56	93.3%	0	• Patient was restless and had removed the probes attached • Nurse had to attend to the procedure for the second patient
Daley by < 2 mins	4	6.7%		
Delay > 2 mins to 5 mins	0	0		
Delay > 5 mins				

As shown in Table 3, observations during morning and evening shifts indicated that for mechanical ventilator alarms, 86.7% of nurses responded within two minutes, whereas 13.3% took between two and five minutes. Delays were primarily due to the presence of water in ventilator circuits, disconnected masks, or simultaneous patient assignments. For infusion pump alarms, 83.3% responded within two minutes, whereas 16.7% took two to five minutes due to medication changes or IV line complications. No false alarms were recorded. In terms of patient monitoring, 93.3% of the nurses responded within two minutes, whereas 6.7% took longer, mainly because of patient restlessness and detached probes.

Obstacles to Alarm Management

Table 4
Ranking of obstacles to alarm management

Ranking		1	2	3	4	5	6	7	8	9
S.no	Item									
1	Frequent false alarms, which lead to reduced attention or response to alarms when they occur	5%	16.7%	20%	13.3%	11.7%	5%	13.3%	1.7%	13.3%
2	Difficulty in understanding the priority of an alarm	5%	8.3%	11.7%	18.3%	11.7%	13.3%	13.3%	15%	3.34%
3	Inadequate staff to respond to alarms as they occur	55%	5%	6.7%	11.6%	5%	8.3%	1.7%	1.7%	5%
4	Difficulty in hearing alarms when they occur	8.3%	11.7%	15%	10%	15%	6.7%	15%	13.3%	5%
5	Difficulty in identifying the source of an alarm	1.7%	20%	11.7%	16.7%	15%	20%	8.3%	3.3%	3.3%
6	Over reliance on alarms to call attention to patient problems	10%	18.3%	8.3%	5%	16.7%	21.7%	5%	5%	10%
7	Noise competition from nonclinical alarms and pages	11.7%	6.7%	18.3%	8.3%	5%	8.3%	10%	15%	16.7%
8	Lack of training on alarm systems	1.7%	3.3%	1.7%	15%	11.7%	8.3%	21.7%	8.3%	28.3%
9	Difficulty in setting alarms properly	0	3.3%	10%	6.7%	13.3%	11.7%	10%	28.3%	16.7%

Table 4 presents the responses related to alarm fatigue. The ranking of obstacles to alarm management identified inadequate staffing as the primary challenge (55%, ranking it as the highest obstacle). The order of

ranking for the first V obstacles was inadequate staff to respond to alarms as they occur, difficulty in identifying the source of an alarm (20%), frequent false alarms leading to reduced attention (20%), difficulty in understanding the priority of an alarm (18.3%), noise competition from nonclinical alarms (18.3%) and overreliance on alarms to detect patient problems (16.7%), as shown in Fig. 1.

Clinical Alarm Fatigue

Table 5
Clinical alarm fatigue among ICU nurses

S.no	Items	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1	I am bothered in everything by clinical alarms	15%	23.4%	28.3%	20%	13.3%
2	I feel anxious due to clinical alarm	5%	28.4%	33.3%	30%	3.3%
3	I feel out of my mind due to the clinical alarms	3.3%	23.3%	33.4%	26.7%	13.3%
4	I have trouble paying attention due to clinical alarms	5%	16.7%	36.7%	33.3%	8.3%
5	I easily forget what I am going to do due to clinical alarms	10%	15%	30%	33.4%	11.6%
6	I feel bad due to clinical alarms	1.7%	30%	31.7%	26.6%	10%
7	I have a headache caused by clinical alarms	13.3%	30%	21.7%	26.7%	8.3%

The assessment of clinical alarm fatigue among ICU nurses indicated that a substantial proportion reported feeling anxious (strongly agree: 40%, agree: 30%), experiencing trouble concentrating (strongly agree: 35%, agree: 30%), and suffering from headaches (strongly agree: 25%, agree: 33.3%). Additionally, 28.3% of the nurses were neutral, and 13.3% strongly disagreed that they were constantly bothered by clinical alarms. A total of 33.3% were neutral, whereas 3.3% strongly disagreed with feeling anxious due to alarms. Furthermore, 31.7% agreed, and 26.6% strongly agreed that alarms contributed to feelings of distress. Headaches related to alarm fatigue were reported by 30% (agree) and 26.7% (strongly agree) of the nurses. The findings suggest that alarm fatigue is prevalent and significantly impacts nurses' cognitive and emotional well-being. (Table 5).

Discussion

The findings of this study highlight several key areas requiring attention and intervention to improve alarm management and reduce alarm fatigue in ICU settings. The high awareness levels among ICU nurses regarding clinical alarm systems were encouraging, indicating that knowledge deficits are not the primary cause of alarm fatigue. However, significant obstacles, such as inadequate staffing and task prioritization issues, were major contributors to delayed responses and overall alarm fatigue. In-service education on cardiac monitoring settings has led to a decrease in the number of alarms per patient per day, and the advent of newer monitoring devices necessitates continuous education on alarm settings and management.(15)

A qualitative systematic review revealed that educational programs on alarm management improved alarm management capabilities and reduced alarm fatigue. (16) One of the findings reported was staffing inadequacies. With 55% of nurses identifying this as a major obstacle, it is evident that insufficient staff coverage compromises the ability to respond to multiple alarms effectively. When nurses are required to care for multiple patients simultaneously, their ability to prioritize alarms and provide timely responses diminishes. Previous studies have consistently shown that understaffing exacerbates cognitive overload and alarm fatigue(17). Therefore, one recommendation is for healthcare institutions to reassess staffing models and consider deploying dedicated personnel for alarm monitoring.

Another significant obstacle was the difficulty in identifying the source of alarms, reported by 40% of the participants. This finding underscores the need for technological improvements in alarm systems. Integrating advanced clinical alerting systems that provide clear and distinguishable alarm notifications can help mitigate this issue. For example, smart alarm systems that differentiate between high-priority and low-priority alarms have been shown to improve response times and reduce alarm fatigue(18).

The discussion also exetnds to the impact of frequent false alarms. A large proportion of nonactionable alarms desensitize nurses, making them less likely to respond promptly. Studies suggest that up to 90% of alarms in ICUs may not require clinical intervention, leading to what is commonly referred to as the "cry wolf" phenomenon(7). Addressing this issue requires hospitals to customize alarm thresholds on the basis of individual patient needs, which could significantly reduce the occurrence of false alarms. Additionally, the study highlighted the physical and cognitive effects of alarm fatigue. Nurses who experienced symptoms such as headaches, decreased attention, and irritability reported reduced job satisfaction and performance. This finding is consistent with those of previous studies, which identified alarm fatigue as a contributing factor to burnout among healthcare workers(12). Health care worker safety measures and a reduction in emotional demands can reduce fatigue and improve patient safety.(19) Organizational interventions such as mindfulness training, regular breaks, and mental health support could help alleviate some of these effects.

A critical aspect to consider is the role of continuous education and training in alarm management. Although most nurses in this study had adequate knowledge of alarm systems, ongoing training programs that focus on practical skills, such as prioritizing alarms and troubleshooting alarm-related issues, are essential. Simulation-based training has been shown to improve nurses' competency in managing complex alarm scenarios(20) (Ruppel et al., 2018). Moreover, fostering a collaborative work environment where nurses, physicians, and technical staff work together to optimize alarm settings can further enhance alarm management. Multidisciplinary teams can review alarm data periodically, identify trends, and implement corrective actions. The use of technology, such as data-driven dashboards, can provide real-time insights into alarm frequencies and patterns, allowing proactive management.

Finally, investing in innovative solutions such as wearable devices and mobile alerts could transform alarm management. Mobile devices that send customized alerts to the appropriate caregiver reduce the overall noise in ICUs and improve response times. For example, integrating alarm systems with nurses' smartphones ensures that critical alarms are directed to the right individual, minimizing unnecessary disruptions(21). In conclusion, addressing alarm fatigue requires a multifaceted approach that includes organizational, technological, and educational interventions. By addressing the root causes of alarm fatigue and optimizing

alarm systems, healthcare institutions can create safer and more efficient environments for both patients and staff.

Conclusion

The study demonstrated that while ICU nurses possess adequate awareness of clinical alarms, alarm fatigue remains a significant concern because of obstacles in alarm management and frequent nonactionable alarms. Strategies targeting staffing, alarm customization, and nurse training are essential to mitigate these issues.

Implications for nursing practice

To address alarm fatigue in ICUs, healthcare organizations should implement strategic interventions focused on policies, training, and technology. Organizational policies must be designed to minimize nonessential alarms while ensuring that critical alerts receive priority attention. Regular training programs on alarm management and fatigue prevention enhance nurses' ability to respond effectively to alarms while reducing stress. Additionally, integrating advanced alerting systems that filter and prioritize alarms on the basis of clinical significance can improve response efficiency, ultimately increasing patient safety and nurses' workflow.

Limitations

The present study had the following limitations as only nurses working in two intensive care units were included in the study, The study did not include the nurse managers of these units and only included the direct caregiving nurses.

Recommendations for future research

Future research should focus on evaluating the effectiveness of alarm reduction strategies across various ICU settings to determine best practices. Investigating the impact of alarm fatigue on patient outcomes will provide valuable insights into its consequences and the need for targeted interventions. By addressing these challenges, healthcare organizations can increase patient safety, create a more supportive work environment for nurses, and minimize the negative effects of excessive alarms in ICUs.

Declarations

Ethics approval and consent to participate: Ethical clearance for the study was obtained from the Institutional Ethics Committee (Ref: CSP/21/Sept/99/487). The study was conducted in full accordance with the ethical standards and the principles outlined in the Declaration of Helsinki (2013 revision), ICMR guidelines on biomedical research in human beings and principles of Good clinical practice with formal permission from the Institutional Ethics Committee for student projects of Sri Ramachandra Institute of Higher Education and Research. The researcher explained the study's purpose, procedures, potential risks, and benefits to all participants. Written informed consent was obtained from each participant prior to data collection. Participants were assured of the confidentiality and anonymity of their responses, and their participation was entirely voluntary. All data were handled in compliance with applicable ethical guidelines to ensure the privacy and rights of the participants were protected throughout the study.

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Figures

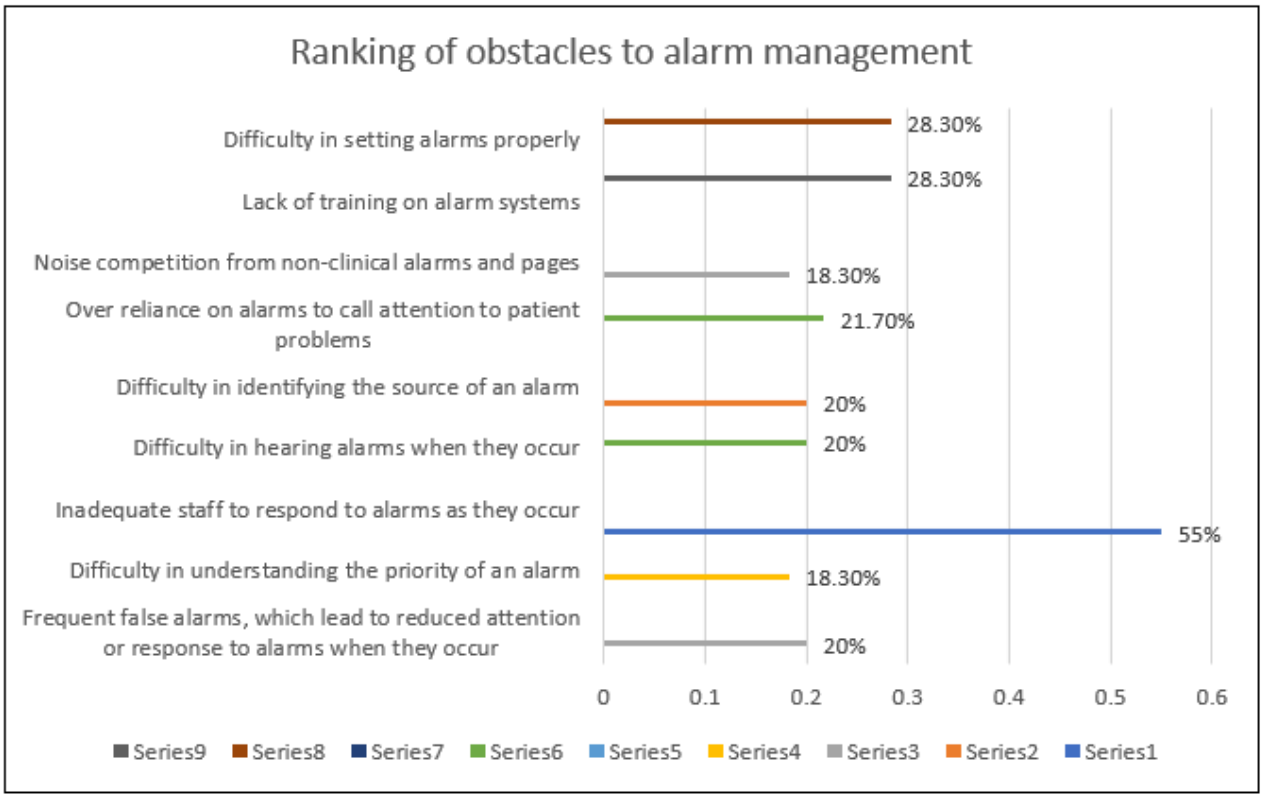

Figure 1

Ranking of obstacles to alarm management