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Research Article

A Quasi-Experimental Study to Assess the Effectiveness of Safe Alarm Practices on Reducing False Alarms, Alarm Burden, and Alarm Fatigue among Nurses in the Paediatric Intensive care unit and Cardio Thoracic Intensive Care Unit at Apollo Children's Hospital, Chennai

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Abstract

Alarm fatigue has emerged as a critical patient safety issue in intensive care units due to the high frequency of alarms generated by biomedical monitoring devices. Evidence indicates that approximately 72–99% of clinical alarms are false or non-actionable, leading to alarm desensitization among healthcare professionals and delayed responses to true critical events. This quality improvement project aimed to reduce alarm burden and alarm fatigue among nurses, improve alarm response time, and enhance patient safety in the Paediatric and Cardio-Thoracic Intensive Care Units (PICU/CTICU). The study was conducted over a three-month period using a quasi-experimental one-group pre-test and post-test design. Interventions included baseline audits of alarm frequency and response patterns, staff sensitization, competency mapping, structured training on safe alarm practices, and reinforcement strategies. Post-intervention analysis revealed a 58.3% reduction in alarms per bed per hour, a 55% reduction in nuisance alarms, and a 52% reduction in false alarms. Nurses' competency scores and consultant satisfaction demonstrated statistically significant improvement ($p < 0.05$). Sustainability of outcomes was ensured through integration of safe alarm practices into unit policies, ongoing competency-based training, periodic alarm audits, and continuous monitoring through quality indicators. The findings indicate that sustained implementation of safe alarm practices effectively reduces alarm fatigue, optimizes alarm management, and improves patient safety outcomes in critical care settings.

Keywords: *Alarm fatigue; ICU; Patient safety; Biomedical alarms; Nurse competency; Quality improvement.*

INTRODUCTION

Clinical alarms are a critical component of patient monitoring systems and play a vital role in the early detection of physiological deterioration in critically ill patients, particularly in intensive care units (ICUs).[1,2] Advances in biomedical technology have increased the use of cardiac monitors, ventilators, infusion pumps, and pulse oximeters; however, these devices generate a high volume of alarms, many of which are clinically insignificant.[3,4] Evidence suggests that nearly 72–99% of clinical alarms are false or non-actionable, contributing to excessive noise, workflow disruption, and desensitization of healthcare professionals.[5,6]

Alarm fatigue is defined as a sensory overload condition in which clinicians become less responsive to alarms due to frequent exposure, leading to delayed or missed responses to true critical events.[7,8] Cvach reported that more than 80–90% of monitor alarms do not require clinical intervention, thereby increasing the risk of alarm fatigue among nurses.[5]

Sendelbach and Funk identified alarm fatigue as a major patient safety concern and emphasized its association with delayed clinical responses and adverse patient outcomes.[6]

In paediatric intensive care units (PICUs), alarm management presents unique challenges due to age-specific physiological variations, frequent patient movement, and the need for narrow alarm limits.[9,10] Studies have shown that inappropriate default alarm settings, poor sensor application, and lack of individualized alarm customization significantly contribute to false alarm generation.[11,12] Welch highlighted that improper alarm thresholds and inadequate staff training are key contributors to alarm overload in critical care environments.[13]

Excessive alarm noise has been associated with increased stress, sleep disturbance in patients, parental anxiety, and burnout among nursing staff.[14,15] Jung et al. demonstrated that alarm overload negatively impacts nurse concentration, decision-making, and overall quality of care.[16] Bridi et al. emphasized that inadequate knowledge and competency in alarm management among nurses further intensifies alarm fatigue, reinforcing the need for structured education and competency-based training programs.[17]

Recognizing the magnitude of this issue, regulatory and professional bodies such as The Joint Commission and the American Association of Critical-Care Nurses have identified clinical alarm safety as a national patient safety priority and recommended standardized alarm management protocols, staff education, and continuous monitoring. [18,19] Funk et al. further advocated integrating alarm safety practices into organizational culture to achieve sustainable improvements in patient safety. [20]

METHODOLOGY

A quasi-experimental one-group pre and post intervention research design was adopted to evaluate the effectiveness of safe alarm practices. The objectives of this quality improvement study were to reduce the frequency of false alarms in the intensive care unit, improve nurses' response time and compliance with alarm safety protocols, identify and mitigate risks associated with excessive and non-actionable alarms, enhance nurses' knowledge and competency in biomedical alarm management through structured training, improve patient safety by reducing alarm fatigue, and standardize safe alarm practices to achieve zero consultant and patient complaints related to clinical alarms. The study was conducted in the 16-bedded Paediatric Intensive Care Unit (PICU) and Cardio-Thoracic Intensive Care Unit (CTICU) at Apollo Children's Hospital, Chennai, over a period of three months from June 2025 to August 2025. The study population comprised all nurses working in the PICU and CTICU at Apollo Children's Hospital, Chennai. A non-probability census sampling technique was employed, and the sample size included all 50 nurses working in the PICU and CTICU during the study period. Safe alarm practices were considered the independent variable, while alarm burden and alarm fatigue were the dependent variables. Data were collected using direct observation, alarm log analysis, staff surveys, and competency mapping tools. The study was implemented in four phases: Pre-analysis involving baseline audit and feedback collection; sensitization and training through structured sessions. Post-analysis and reinforcement with repeat audits and competency reassessment; and a sustenance phase focusing on embedding safe alarm practices into routine hospital culture with ongoing monitoring.

Tools for Data Collection:

The tools used for data collection included a structured alarm audit checklist to record alarm frequency and types, a nurse competency assessment questionnaire on alarm management, a consultant satisfaction survey, and alarm log extraction formats from monitoring systems.

Tool 1 was the structured alarm audit Checklist was a structured observational tool used to record and analyze clinical alarm events during a one-hour direct observation period in the selected unit. It captured data on equipment generating alarms (patient monitors, ventilators, infusion pumps), alarm color coding, type of alarm (true, false, or nuisance), alarm description, silencing practices, and actions taken by healthcare staff. This tool enabled objective measurement of alarm frequency, alarm burden, and response behaviors, thereby supporting evaluation of baseline and post-intervention alarm management practices.

Tool 2 was Consultant Feedback Survey on Clinical Alarm Management was a structured questionnaire designed to assess consultants' perceptions regarding the effectiveness and impact of clinical alarm management on patient care and clinical workflow. Using a five-point Likert scale, the survey evaluated alarm frequency, interruption due to false alarms, clarity of alarm sounds, effect on communication and concentration, and overall alarm system effectiveness. An open-ended section allowed consultants to provide qualitative suggestions, supporting comprehensive assessment of alarm management outcomes before and after intervention.

Tool 3 was assessment Questionnaire for Nurses on Clinical Alarm Safety used to assess nurses' knowledge and awareness of alarm priority levels, color coding, alarm limit setting, types of alarms, alarm fatigue, and the importance of alarm management in patient safety. Consisting of ten closed-ended questions in yes/no, multiple-choice, and true/false

formats, the questionnaire was administered as a pre- and post-test to evaluate the effectiveness of educational interventions aimed at improving safe clinical alarm practices.

Ethical Considerations

Institutional permission was obtained prior to conducting the study. Participation was voluntary, confidentiality of participants was maintained. The study posed no risk to patients or healthcare providers and adhered to ethical principles of research.

RESULTS

Data were analyzed using both descriptive and inferential statistics to evaluate the effectiveness of the clinical alarm safety intervention. Descriptive statistics summarized alarm frequency, alarm types, nurse competency scores, and consultant satisfaction. Inferential statistics using paired t-tests determined the significance of differences between pre- and post-intervention phases. The pre-intervention alarm rate of 9.5 alarms per bed per hour reduced to 6 alarms per bed per hour post-intervention, indicating a 58.3% reduction. False alarms reduced by 52% and nuisance alarms by 55%, while true alarms increased by 25%. Nurse competency scores and consultant satisfaction showed statistically significant improvement ($p < 0.05$).

Section I -Table 1: Comparative statistical table to depict Alarms pre and post-intervention

Alarm Type	Mean/Pre-intervention	Mean Post intervention	Standard Deviation (Pre)	Standard Deviation (Post)	Mean Difference	Paired *t* Value	*P* Value
True Alarm	2.50	3.12	0.82	0.74	0.62	4.28	$p < 0.05$
False Alarm	2.62	1.25	0.91	0.66	1.37	9.16	$p < 0.05$
Nuisance Alarm	4.25	1.87	1.10	0.72	2.38	11.84	$p < 0.05$

The Table 1 shows that a paired-samples *t*-test was performed to determine the effectiveness of the clinical alarm safety intervention on the reduction of false and nuisance alarms in the PICU/CTICU. The analysis revealed a statistically significant reduction in both alarm categories following the intervention. The mean false alarm rate decreased from the pre-intervention phase (M = 2.62, SD = 0.91) to the post-intervention phase (M = 1.25, SD = 0.66). The mean difference of 1.37 was statistically significant ($t = 9.16$, $p < 0.05$).

Similarly, nuisance alarms showed a substantial decline, with the pre-intervention mean (M = 4.25, SD = 1.10) reducing to a post-intervention mean of 1.87 (SD = 0.72). The mean difference of 2.38 was found to be statistically significant ($t = 11.84$, $p < 0.05$). These findings indicate that the structured training and safe alarm practice interventions were effective in minimizing non-actionable alarms, thereby reducing alarm fatigue and improving the clinical work environment for nurses.

Table 2: Comparison of Mean and Standard Deviation of Overall Alarm Reduction Pre and Post-Intervention

Alarm Burden	Mean (Pre-intervention)	Mean (Post-intervention)	Standard Deviation (Pre)	Standard Deviation (Post)	Mean Difference	Paired t Value	P Value
Alarms per Bed per Hour	9.50	6.00	1.48	1.02	3.50	10.62	$p < 0.05$

Reduction Percentage $\frac{9.5-6.0}{9.5} \times 100 = 58.3\%$

The Table 2 indicates that a paired-samples *t*-test was conducted to evaluate the effectiveness of the clinical alarm safety intervention on alarm burden in the PICU/CTICU. The results demonstrated a statistically significant reduction in alarm frequency following the intervention. The pre-intervention mean alarm rate (M = 9.50, SD = 1.48) decreased to a post-intervention mean of 6.00 alarms per bed per hour (SD = 1.02). The mean difference of 3.50 alarms was statistically significant ($t = 10.62$, $p < 0.05$), indicating that the implementation of safe alarm practices effectively reduced overall alarm burden and contributed to minimizing alarm fatigue among nurses.

Section II: Comparison of Mean and Standard Deviation of Nurses compliance Pre- and Post-Intervention

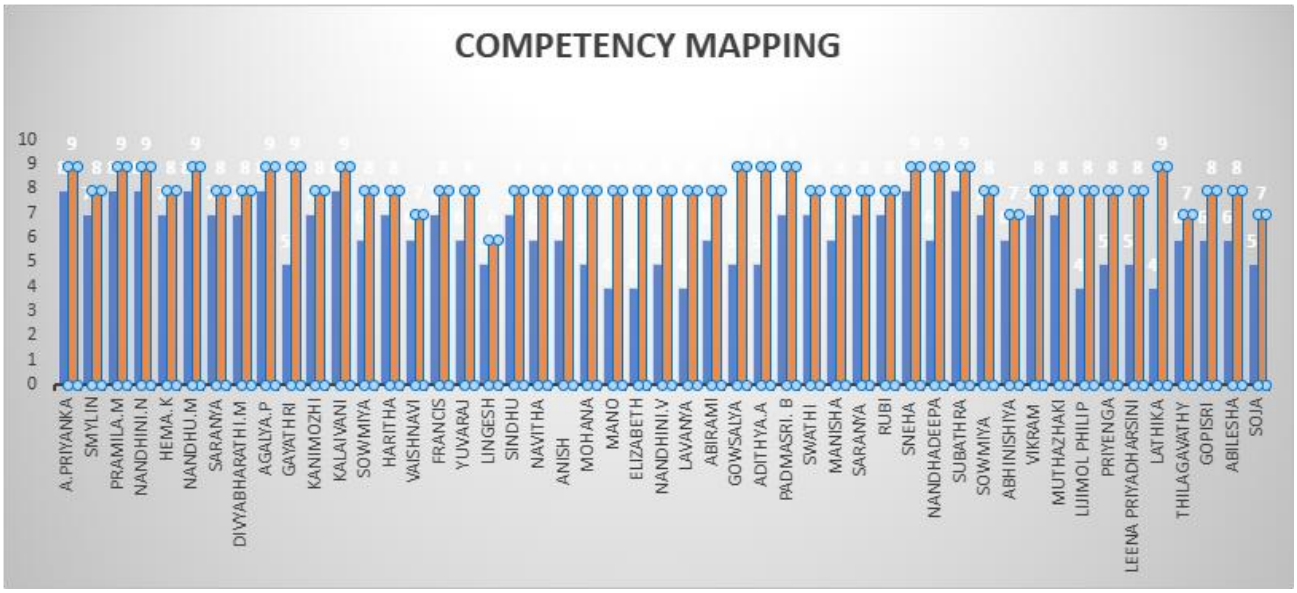

Fig 1: clustered horizontal bar graph showing nurses total level of knowledge related to clinical alarm management pre and post intervention

Table 3: Comparison of Mean and Standard Deviation of Nurses' Competency Mapping

Nurses Competency Mapping	Mean		Standard Deviation		Mean difference	Paired t value	'P' Value
	Pretest	Posttest	Pretest	Posttest			
	6.22	8.14	1.23	0.67	1.92	11.55	p is <0.05

The table 3 reveals that a paired-samples t-test was conducted to assess the effectiveness of the clinical alarm safety intervention on nurses' competency scores. Results showed a statistically significant improvement in competency following the intervention. The pre-test mean score (M = 6.22, SD = 1.23) increased to a post-test mean score of 8.14 (SD = 0.67). The mean difference of 1.92 was statistically significant (t = 11.55, p < 0.05), indicating that the training program had a positive impact on nurses' knowledge and skills related to alarm management.

Section III: Comparison of Mean and Standard Deviation Consultant Satisfaction Survey pre and post training and intervention

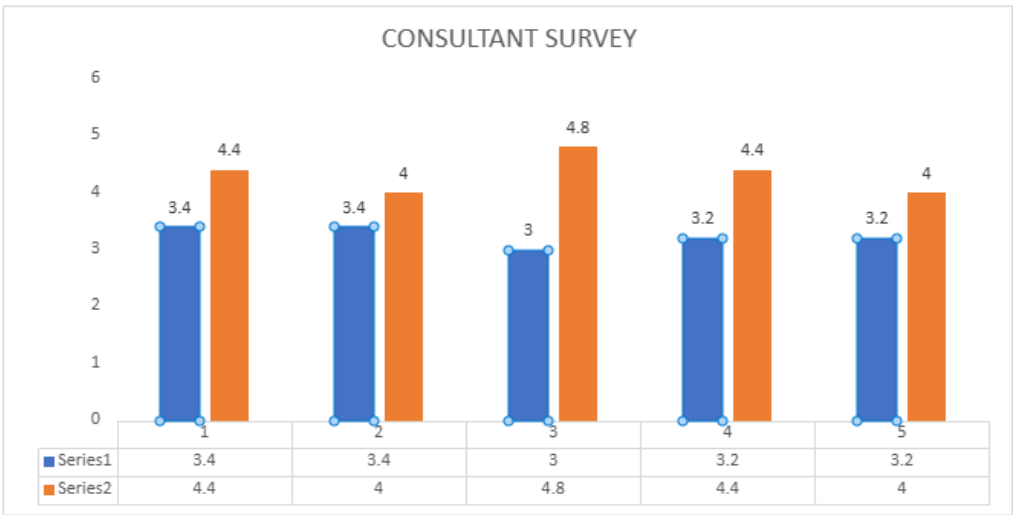

Fig 2: Paired horizontal bar graph showing improved consultant satisfaction pre and post intervention

Table 4: Comparison of Mean and Standard Deviation of Consultant Survey

Consultant Survey	Mean		Standard Deviation		Mean difference	Paired t value	'P' Value
	Pretest	Posttest	Pretest	Posttest	1.08	5.24	p is <0.05
	3.24	4.32	0.16	0.33			

The Table 4 depicts a paired samples t-test was performed to evaluate changes in consultant satisfaction before and after implementation of clinical alarm safety interventions. The findings indicated a significant improvement in consultant perception following the intervention. The mean pre-test score (M = 3.24, SD = 0.16) increased to a posttest score of (M = 4.32, SD = 0.33), yielding a mean difference of 1.08. The calculated t-value of 5.24 with a p-value < 0.05 confirms that the change was statistically significant. These results suggest that the intervention positively influenced consultant satisfaction related to alarm management practices and patient safety responsiveness.

DISCUSSION

The study demonstrated that structured training, alarm customization, and reinforcement activities significantly reduced alarm fatigue and alarm burden. Improved nurse competency contributed to faster response times and better alarm management. Integration of alarm safety practices into routine care ensured sustainability despite initial resistance to change.

CONCLUSION

Clinical alarm safety is a critical patient safety concern in intensive care units. This quality improvement project demonstrated that alarm fatigue can be effectively reduced through staff sensitization, competency-based training, and standardized alarm management protocols. Sustained improvements in patient safety, nurse efficiency, and consultant satisfaction highlight the importance of embedding safe alarm practices into hospital culture.

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