Effect of Implementing an Educational Intervention about Managing Alarm Fatigue on Improving Clinical Practices of Pediatric Critical Care Nurses

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Abstract

Background: Educating nurses on alarm management & alarm fatigue can help in maintaining their knowledge and abilities in complex clinical settings as well as improving the pediatric patient safety. So**,** the current study was conducted to evaluate the effect of implementing an educational intervention for pediatric critical care nurses on managing alarm fatigue and improving clinical alarm management practices. **Methods:** A quasi-experimental design was utilized during the current study, and it was conducted on 70 pediatric nurses who are concerned in providing direct care in the intensive care units at Mansoura University Children Hospital. **Results:** Since the majority of the nurses under investigation were competent post-intervention compared to being incompetent pre-intervention, the educational intervention showed a highly statistical improvement in the total practice levels among the nurses throughout the research period. Additionally, nurses noted a significant improvement in alarm fatigue symptoms post-intervention compared to pre-intervention, with a highly statistically significant difference. **Conclusion & Recommendations:** The educational intervention seems to improve nurses' knowledge and practice regarding alarm system monitoring and management and help in minimizing alarm fatigue symptoms. Therefore, the researchers recommended implementing comprehensive educational interventions and provide resources for continued learning and address staffing and workload issues. As well, encourage interdisciplinary collaboration and promote a culture of safety and accountability for nursing staff.

Keywords: alarm fatigue; alarm fatigue management; clinical alarms; educational intervention; pediatric critical care nurse.

Introduction

Clinical alarms are placed next to pediatric patients' bedsides in pediatric critical care units to provide the best possible clinical intervention since alarm fatigue is a key problem for pediatric patient safety. In critical care facilities, the pediatric patient is surrounded by various monitoring, diagnostic, and therapeutic gadgets **(Deck, 2016)**. All gadgets include alarm functions that produce both visual and audible alarms to notify the personnel of changes in the patient's state or an equipment breakdown. Clinical alarms, which notify critical care nurses to a major clinical occurrence, are intended to facilitate urgent pediatric patient monitoring in a manner similar to this. In contrast, the massiveness of these alerts diminishes their significance **(Cvach, 2012).**

A lack of motivation to act is the definition of fatigue. It may be transient (acute), disappearing after a period of rest, or it may be permanent (chronic), marked by constant physical and mental fatigue. According to **Sendelbach (2012)**, alarm fatigue is the result of being exposed to the monitoring device's stimulation too much. Alarm fatigue in nurses is a result of inconsistent nursing practice and an

overuse of clinical alerts. Nurses may react to alerts slowly or dismiss them entirely due to sensory overload caused on by so many alarms **(Lewandowska et al., 2020)**. Additionally, staff fatigue may be caused by monitoring device alerts for a variety of causes. It is challenging to locate the warning, assess it, and determine where it came from. When employed in an ICU, a variety of monitoring devices generate alerts with various levels of importance. The disruption of work-related tasks, separation from them, and priority of the alarm's importance are the main causes of cognitive stress that nurses suffer as a result of alerts, which occurs most of the time **(Ruskin & Hueske-Kraus, 2015; Lewandowska et al., 2020).**

Pediatric nurses, who spend the majority of their time with the patients and monitor their condition round-the-clock, are particularly at risk from alarm fatigue. When a nurse is on duty, there are about 150 to 400 alarms created besides. Pediatric nurses who work in ICUs spend about 35% of their time only responding to alarms **(Lewis & Oster, 2019).** Because the alarms are often associated with a screening abnormality, such as an abnormal respiration rate, blood pressure, pulse oximeter reading, incubator troubleshooting or cardiac rhythm, and each alarm is combined with an audible and visual warning **(Lukasiewicz & Mattox, 2015),** these results in the alarm fatigue which is the sensory load and desensitization that nurses face when subjected to a high volume of alarms, and has been listed as one of the "Top Ten Health Technology Hazards" in acute care settings by hospital safety organizations **(Brantley et al., 2016).**

Nowadays, the hospital environment becomes noisier as a result of the high levels of modern technology's introduction of ever-more-sophisticated instruments, and the illusion of safety that technology should supposedly ensure turns out to be deceptive **(Petersen & Costanzo, 2017).** Overuse of clinical alarms can result in an alarm hazard, which includes alarm fatigue, inappropriate alarm use, and applying the same alarm range to all patients. This hazard has been defined as a failure to respond to an alarm in a sufficient manner as well as a poor management of alarms or their settings **(Sowan etal., 2017).** Nursing staff also need to have time to divide their focus between treating patients and responding to signals from multiple medical equipment now more than ever before **(Top, E. C. R. I., 2019).**

Alarm fatigue occurs when there are too many clinical alerts for the medical personnel to manage; in particular, false (positive) alarms, inaccuracies in alarm-setting ranges, and overuse of patient monitors are the major causes of alarm fatigue **(Christensen, 2014)**. The most severe and frequent of these obstacles is false alarms, which can have the "cry-wolf" effect and cause nurses to misread crucial signals and fail to respond effectively. In addition, it can make warning systems less reliable and deter nurses from utilizing alarm devices **(Sendelbach, 2012; ERCI Institute, 2007)**. As a result, it is critical to effectively manage medical device alerts and develop solutions that can reduce the number of false alarms.

Since 2010, standardized prevention has been advocated based on several studies on how to conceptualize and lessen alarm fatigue **(Cvach et al., 2013 and Gazarian, 2014),** and fundamental research on nurses' clinical alarm detection and the barriers to their alarm management, and basic research on nurses' recognition of clinical alarms and on the obstacles to their alarm management in the United States **(Funk et al., 2014 and ERGİN, 2023).**

Significance of the study

By reviewing the literature on the management of clinical alarms by nursing staff in pediatric intensive care units revealed major gaps in the body of knowledge on alarm fatigue. The Joint Commission has advocated for clinical care team members to get training and education on clinical alarms and alarm management and has underlined that new team members should continue to receive education to increase alarm safety in hospitals **(The Joint Commission, 2013).** The essential question remains: how successful are these educational interventions in reducing alarm fatigue in nurses. More literature has recently appeared on various education and training initiatives. Therefore, our study was carried out based on this concept.

Aim of the study

The aim of the current study was to evaluate the effect of implementing an educational intervention for pediatric critical care nurses on managing alarm fatigue and improving clinical alarm management practices. The following study goals & objective examined by the researchers as follow: first, assessment of the alarm fatigue as seen and reported by pediatric critical care nurses. Second, identify the nursing perspective's barriers to managing clinical alarms. Third: Planning and executing a nurse educational intervention program on clinical alarm management systems and alarm fatigue. As well evaluate the results of employing educational intervention.

Research hypothesis examined and evaluated by the researchers as follow: first, following the implementation of the educational intervention, PICU nurses have good practices regarding clinical alarm management. Second, following the implementation of the educational intervention, alarm fatigue symptoms among PICU nurses have decreased.

Materials and Methods

Study design and setting

To achieve the study's goal, a quasi-experimental research design with a single group (pre- and post-test measurements) was used. The Mansoura University Children's Hospital (MUCH), which is affiliated to Mansoura University in Egypt, has four pediatric intensive care units: the Neonatal Intensive Care Unit (NICU), Pediatric Intensive Care Unit (PICU), Surgical Intensive Care Unit (SICU), and Cardiac Care Unit (CCU) were included in the study.

Participants:

A convenience sample of 70 pediatric nurses with more than one year of experience providing direct patient care in the study location indicated above, independent of their educational background and certification, participated in the current study. Nurses who agreed to participate in the study and gave their approval were accepted.

Calculating the sample size

The sample size was estimated using the method below utilizing data from the literature (Casey et al., 2018), level of significance of 5%, and power of research of 80%.

$$n = \frac{2(Z\alpha/2 + Z\beta)\text{^}2 \times p\ (1-p)}{(d)\text{^}2}$$

Where: d = predicted difference in percentage of occurrences; p = pooled proportion from prior study; Z/2 = 1.96 (for 5% threshold of significance); and Z = 0.84 (for 80% power of study). As a result, $n = \frac{2(1.96 + 0.84)^2 \times 0.92\ (1-0.92)}{(0.13)\text{^}2} = 68.3$. Consequently, 69 samples are needed.

Instruments of Data Collection:

The researchers utilized five tools to collect the data namely: nurses' knowledge about clinical alarms and alarm fatigue. This instrument including two parts. Part I: covers the demographic information about pediatric critical care nurses, including their age, years of experience, gender, degree of education, location of employment, and number of weekly working hours. The researcher created Part II to evaluate nurses' alarm knowledge, which included 13 items, and their alarm fatigue knowledge, which included 6 items. A total of 19 multiple-choice questions were used before and after the educational intervention, with the correct response receiving one mark and the incorrect response receiving zero. The marks earned for each item were added together to get the highest possible score for nurses' knowledge, which was 19. Nurses' knowledge was evaluated overall and classified as follows: knowledge levels of 80% or more were regarded "Good," knowledge levels of 70–80% were rated "Average," and knowledge levels of less than 70% were considered "Poor."

The second tool was nurses' symptoms of clinical alarm fatigue; from the list of subjective symptoms of alarm fatigue updated by the **Japanese Occupational Hygiene Association** in **2002**, eight pertinent elements were chosen. In the end, seven items were adopted, with the exception of one with a content validity rating below 0.8. A 5-point scale was used to grade each item, with a higher

score indicating more fatigue. Tool 3 nurses' attitude toward clinical alarms that includes 24 items suitable for the Egyptian ICU context were chosen from a total of 31 items created by the **Healthcare Technology Foundation (HTF), (2006),** and verified by translation and reverse translation. This instrument examines ICU nurses' attitudes about medical device alarms. A 5-point scale was used for measurement, with 1 denoting "always," 2 denoting "usually," 3 denoting "occasionally," 2 denoting "rarely," and 5 denoting "never." While 10 items had inverted scores, with 5 denoting "always" and 1 denoting "ever."

The fourth tool was to evaluate pediatric nurses' practices regarding alarms management in accordance with international guidelines for intensive care units, **Han, in 2016** developed the Alarm Management Checklist, which was used to measure alarm management **(Lewis & Oster, 2019; Phillips, et al., 2020).** In particular, professional advice and current care standards were used as the foundation for the questions about nurses' alarm handling practices. The accuracy of the electrocardiogram (ECG) electrodes, skin preparation (5 items), cardiac monitor alarms (9 items), pulse oximetry (5 items), mechanical ventilator (9 items), infusion pump devices (8 items), and incubator clinical alarms (15 items) are among the 51 items measured by this tool. Scoring: Each practical point is valued according to whether it was completed correctly, incorrectly, or not at all. completed correctly (1 point). However, it was done incorrectly and wasn't completed (Zero). An overall score of (51) was calculated using the nurses' performance scores for each phase, with a higher score indicating better alarm management. Scores up to or above 75% were considered to be at a competent practice level, while scores below 75% were considered to be at an incompetent practice level. The fifth tool is the obstacles clinical alarm management challenges; it Included 9 items that dealt with challenges & obstacles to efficient alarm handling. On a 4-point scale from strongly agree to strongly disagree, nurses were asked to rank the obstacles, with highly agreeing reflecting a bigger barrier.

Ethical Consideration

The Research Ethics Committee of the Faculty of Nursing at Mansoura University provided their approval for conducting this study (Ref. No. P.0454). The hospital management and NICU department heads gave their administrative approval. Before include the nurses in the study, written agreement was obtained from them after the study's purpose and its potential risks were made clear. Participants were made aware that all information was coded and that confidentiality was taken into account.

Validity and Reliability of the Study Tools

Study tools was translated into Arabic by the researchers. Five Pediatric Nursing experts tested them for content validity in the Faculty of Nursing, Mansoura University. The tool's reliability was tested through Cronbach's alpha test (α= 0.862, 0.79, 0.95 & 0.957, 0.78 respectively).

The Pilot Study

A pilot study was conducted on 10% (7) of studied nurses to test the study tools' clarity and feasibility and determine the time required to complete the tools. Nurses included in the pilot study was excluded from the study subjects.

Data gathering process:

Data collection of this study carried out over a six -months started from middle of April 2023 to the middle of September 2023. Data collection was conducted through three phases (assessment phase, implementation, and evaluation phase).

The head nurses and nurses in the ICUs were given an explanation of the purpose and nature of the study in the assessment phase. During this phase, the researchers assessed nurses' baseline familiarity with clinical alarms and alarm fatigue (Tool I), as well as the signs of nurse alarm fatigue (Tool II)

An explanation about the aim and nature of the study were discussed with the head nurses and nurses in the ICUs. Throughout this

phase, the investigators measured nurses' baseline knowledge about clinical alarms and alarm fatigue (Tool I), symptoms of clinical alarm fatigue in nurses (Tool II) & nurses' attitude toward alarm (Tool III). In order to evaluate nurses' practical level, the investigators used the alarm management practice checklist; for a period of one month, the researcher observed each nurse for an average of three hours per day, three days per week. The researcher then filled out observational checklists, documented the nurses' practices with regard to the alarm management system (Tool IV), and finally recorded the nurses' challenges with clinical alarm management (Tool V).

For the nurses, the researcher created and implemented an educational intervention in the implementation phase. "Two practical and two theory sessions" made up the program's four sessions. Ten nurses were placed in each group when the nurses were allocated. The program is extensive across a month, with one group meeting per week, lasting between thirty- and forty-five-minutes total. After providing care to the critically ill children, the session took place either during the afternoon shift or during the morning shift. The theoretical sessions concentrated on the definition and types of clinical alarms, clinical alarm levels related to cardiac monitor alarms, causes of weak signal and baseline (no waveform), methods to reduce false alarms, nurses' knowledge of ventilator alarms, syringe pump troubleshooting, pulse oximetry troubleshooting, and methods of preventing alarm fatigue.

The practical session focused on electrode placement and proper skin preparation, modifying the alarm limits based on the patient's condition, managing artifact alarms, false high-rate alarms, weak signal alarms, managing baseline (no waveform) alarms, managing ventilator alarms, managing pulse oximeter alarms, and managing syringe pump alarms. The shift work will be used during every practical session. For every five nurses, nurses were separated into smaller groups for practical sessions that held in the nurses working unit. During the sessions, the nurses were provided with educational materials such as handouts and visual aids to enhance their understanding and retention of the information. The researcher also used interactive teaching methods such as group discussions, case studies, and hands-on practice to actively engage the nurses in the learning process. Using the previously indicated research methodologies, the knowledge and practice of nurses were evaluated before and after the educational intervention had been in place for two months in the evaluation phase.

Statistical Analysis

The data were examined using the Statistical Package for Social Science version 26. The demographic information was analyzed using descriptive statistics, such as means, standard deviations, frequency, and percentages. The student t-test was used to compare quantitative continuous data between before and after the module was implemented. The Fisher's exact test and the Chi-square test were employed to compare qualitative variables. The p-value significance threshold was set at 0.05, and a P-value of 0.001 or above was deemed highly significant.

Results

Table 1 shows that, more than half of the study participant (57.1%), had bachelor's degree in nursing and more than two fifth of them (44.3%) were in the age group of 18- 29 years old with less than 5 years of experience, vast majority of them (92.9%) had no prior training in how to respond to alarms.

Table 2 clarifies that there was overall improvement of the total level of knowledge about clinical alarms and alarm fatigue post intervention compared with pre intervention with a highly statistically significance difference $p<0.001$.

Figure 2 shows that there was overall improvement of the nurses' attitude regarding clinical alarms post intervention compared with pre intervention with a highly statistically significance difference $p<0.001$.

Symptoms of alarm fatigue among the studied nurses were illustrated in table 3 and figure 1 and shows that there is 40% of the studied nurses' responses improved a lot post intervention compared with 8.6% pre

intervention with a highly statistically significance difference p<0.001.

Figure3 shows the total practice levels among the studied nurses all through the study period. It was found that, the highest percentages (65.7%) of them were incompetent practices pre intervention which become competent by 77.1% of them post intervention with a highly statistically significant difference p value<0.001.

Tables 4 compares the nurses' overall levels of practice and demonstrates how the nurses' performance has improved with regard to the proper preparation of the skin for ECG electrodes, cardiac monitor alarms, pulse oximetry monitor (SPO2) and customize settings on oxygen saturation, ventilator alarm troubleshooting, infusion pump troubleshooting alarm, and incubator alarm adjustment to help prevent alarm fatigue post intervention compared to pre intervention. With a p value<0.001, the difference in regard to all nurses' practices was highly statistically significant.

Table 5 explains the study nurses' pre- and post-intervention responses to the obstacles to appropriate clinical alarm management and demonstrates that the post-intervention replies were better than the pre-intervention responses with a highly statistically significant difference of p value<0.001.

Table 6 demonstrates that there was no statistically significant connection with the nurses' age or gender, but there was a highly statistically significant association with the nurses' overall level of knowledge, years of experience, and degree of education post-Intervention. Following the intervention, there was a highly statistically significant correlation between the nurses' overall level of practice and their level of education, but not between their age or gender. In contrast to their age or gender, there was no statistically significant connection between the nurses' attitude level and their years of experience or level of education post-intervention

Table 7 shows that there was a statistically significant association between the nurses' alarm fatigue symptoms with their knowledge, practice, and attitude level post – intervention.

Table 8 reveals that there was a positive correlation between the nurses' knowledge, practice, and attitude level post – Intervention.

Table 1: Socio-demographic characteristics of the studied nurses' (N= 70)

Variables	N (70)	%
Age (Years)		
18 -≥29	31	44.3
30 -≥39	33	47.1
40 -≥49	6	8.6
Mean ±SD	30.17 ±5.91	
Years of experience		
< 5	31	44.3
5 -≥ 10	9	12.9
10 -≥ 15	20	28.6
15 -≥ 20	8	11.4
> 20	2	2.9
Gender		
Male	17	24.3
Female	53	75.7
Level of education		
Diploma in Nursing	13	18.6
Bachelor's degree in nursing	40	57.1
Master's degree in nursing	17	24.3
The department/unit you work for		
Pediatric Intensive Care Unit (PICU)	10	14.3
Neonatal Intensive Care (NICU)	20	28.6
Surgical Intensive Care Unit (SICU)	23	32.9
Cardiac Care Unit (CCU)	17	24.3
Weekly working hours		
Less than 35 hours (4 – 5 hours per day)	12	17.1
35 - 42 hours (5 – 6 hours per day)	23	32.9
More than 42 hours (more than 6 hours per day)	35	50.0
Received any previous training about alarm management		
Yes	5	7.1
No	65	92.9

Table 2. Comparison between nurses' total levels of knowledge pre and post intervention

Variables	Pre – Intervention		2 months Post – Intervention		Test of significance	
	n	%	N	%	X^2	P
Nurse's knowledge about clinical alarms						
Poor Knowledge	46	65.7	10	14.3	44.046	<0.001**
Fair Knowledge	11	15.7	11	15.7		
Good Knowledge	13	18.6	49	70.0		
Nurse's knowledge about Alarm fatigue						
Poor Knowledge	51	72.9	15	21.4	45.252	<0.001**
Fair Knowledge	14	20.0	17	24.3		
Good Knowledge	5	7.1	38	54.3		
Total Knowledge Level						
Poor Knowledge	48	68.6	13	18.6	41.529	<0.001**
Fair Knowledge	12	17.1	13	18.6		
Good Knowledge	10	14.3	44	62.9		

X^2 Chi – Square **: p <.001

Table 3. Comparison of the studied nurses' symptoms of alarm fatigue pre and post intervention

Variables	Pre – Intervention					2 months Post – Intervention					Chi – Square / Fisher's exact test	
	Never	Rarely	Sometimes	Often	Always	Never	Rarely	Sometimes	Often	Always	X^2	P
I am bothered in everything by clinical alarms	0 (0.0%)	2 (2.9%)	27 (38.6%)	26 (37.1%)	15 (21.4%)	1 (1.4%)	37 (52.9%)	8 (11.4%)	15 (21.4%)	9 (12.9%)	47.176	<0.001**
I feel anxious due to clinical alarms	1 (1.4%)	5 (7.1%)	19 (27.1%)	37 (52.9%)	8 (11.4%)	1 (1.4%)	22 (31.4%)	12 (17.1%)	30 (42.9%)	5 (7.1%)	13.708	0.008*
I feel out of my mind due to clinical alarms	0 (0.0%)	5 (7.1%)	13 (18.6%)	44 (62.9%)	8 (11.4%)	0 (0.0%)	17 (24.3%)	23 (32.9%)	22 (31.4%)	8 (11.4%)	16.657	<0.001**
I have trouble paying attention due to clinical alarms	3 (4.3%)	16 (22.9%)	9 (12.9%)	33 (47.1%)	9 (12.9%)	0 (0.0%)	19 (27.1%)	28 (40.0%)	21 (30.0%)	2 (2.9%)	20.135	<0.001**
I easily forget what I am going to do due to clinical alarms	9 (12.9%)	13 (18.6%)	7 (10.0%)	35 (50.0%)	6 (8.6%)	11 (15.7%)	48 (68.6%)	6 (8.6%)	3 (4.3%)	2 (2.9%)	49.306	<0.001**
I feel bad due to clinical alarms	0 (0.0%)	10 (14.3%)	24 (34.3%)	35 (50.0%)	1 (1.4%)	2 (2.9%)	15 (21.4%)	28 (40.0%)	21 (30.0%)	4 (5.7%)	8.608	0.072
I have a headache caused by clinical alarms	0 (0.0%)	8 (11.4%)	29 (41.4%)	30 (42.9%)	3 (4.3%)	2 (2.9%)	10 (14.3%)	33 (47.1%)	23 (32.9%)	2 (2.9%)	3.605	0.462

**: p <.001

Figure 1. Comparison between total score pre and post intervention of the studied nurses' responses toward the Symptoms of alarm fatigue

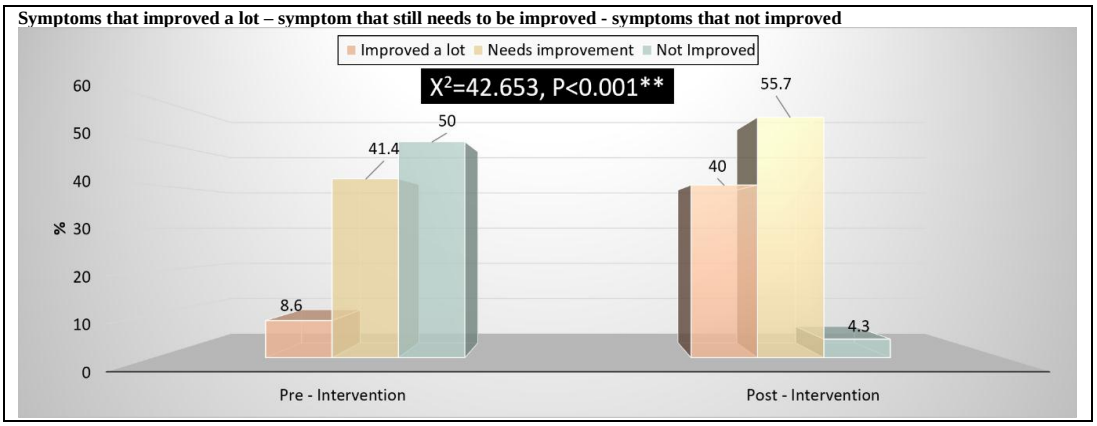

Figure 2. Comparison between nurses' attitude pre and post intervention

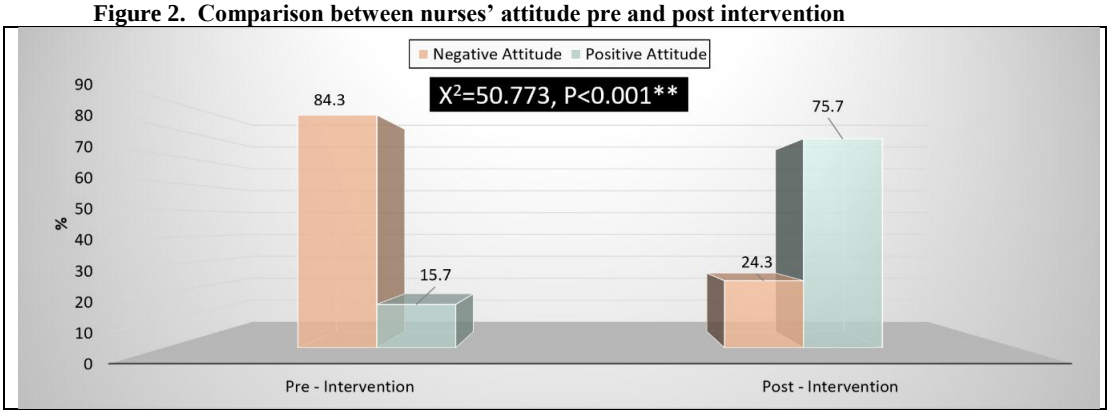

Table 4. Comparison of nurses' total levels of practices pre and post intervention

Variables	Pre – Intervention				2 months Post – Intervention					
	Incompetent		Competent		Incompetent		Competent		Chi – Square	
	n	%	n	%	n	%	n	%	X^2	P
Proper skin preparation for ECG electrodes	40	57.1	30	42.9	19	27.1	51	72.9	12.919	<0.001**
Cardiac Monitor Alarms	50	71.4	20	28.6	15	21.4	55	78.6	35.179	<0.001**
Pulse oximetry monitor (SPO2) and customize settings on oxygen saturation	47	67.1	23	32.9	19	27.1	51	72.9	22.473	<0.001**
Ventilator alarm troubleshooting	43	61.4	27	38.6	14	20.0	56	80.0	24.886	<0.001**
Infusion Pump Troubleshooting Alarm	44	62.9	26	37.1	17	24.3	53	75.7	21.178	<0.001**
Incubators alarm adjustment	42	60.0	28	40.0	19	27.1	51	72.9	15.368	<0.001**
Total Practice Level	46	65.7	24	34.3	16	22.9	54	77.1	26.054	<0.001**

**: p <.001

Figure 3. Comparison of nurses' total levels of practices pre and post intervention

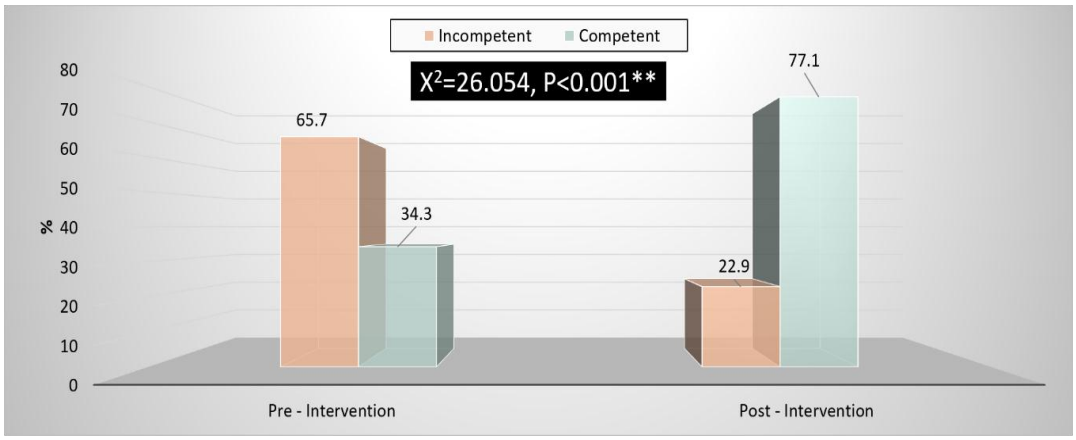

Table 5. Comparison of the studied nurses' responses toward obstacles to proper clinical alarm management pre and post intervention

Variables	Pre – Intervention				2 months Post – Intervention				Chi – Square / Fisher's exact test	
	Strongly Agree	Agree	Disagree	Strongly Disagree	Strongly Agree	Agree	Disagree	Strongly Disagree	X^2	P
Difficulty understanding the priority of the alarm	26 (37.1%)	15 (21.4%)	19 (27.1%)	10 (14.3%)	1 (1.4%)	6 (8.6%)	56 (80.0%)	7 (10.0%)	45.788	<0.001**
Difficulty hearing alarms when they occur	11 (15.7%)	28 (40.0%)	25 (35.7%)	6 (8.6%)	0 (0.0%)	1 (1.4%)	55 (78.6%)	14 (20.0%)	50.588	<0.001**
Frequent false alarms that reduce attention or respond to alarms when they occur	23 (32.9%)	28 (40.0%)	16 (22.9%)	3 (4.3%)	16 (22.9%)	32 (45.7%)	4 (5.7%)	18 (25.7%)	19.437	<0.001**
Difficulty identifying the source of the alarm	19 (27.1%)	28 (40.0%)	18 (25.7%)	5 (7.1%)	1 (1.4%)	3 (4.3%)	36 (51.4%)	30 (42.9%)	60.218	<0.001**
Insufficient numbers of nurses to respond to alarms as they occur	40 (57.1%)	20 (28.6%)	9 (12.9%)	1 (1.4%)	24 (34.3%)	10 (14.3%)	32 (45.7%)	4 (5.7%)	22.036	<0.001**
Difficulty setting alarms correctly	14 (20.0%)	33 (47.1%)	19 (27.1%)	4 (5.7%)	1 (1.4%)	29 (41.4%)	37 (52.9%)	3 (4.3%)	17.453	<0.001**
Over-reliance on alarms to draw attention to patient problems	13 (18.6%)	50 (71.4%)	7 (10.0%)	0 (0.0%)	2 (2.9%)	10 (14.3%)	50 (71.4%)	8 (11.4%)	75.172	<0.001**
Non-clinical noise competition from alarms	37 (52.9%)	28 (40.0%)	4 (5.7%)	1 (1.4%)	6 (8.6%)	19 (27.1%)	43 (61.4%)	2 (2.9%)	56.767	<0.001**
Lack of training on alarm systems	52 (74.3%)	18 (25.7%)	0 (0.0%)	0 (0.0%)	15 (21.4%)	33 (47.1%)	3 (4.3%)	19 (27.1%)	46.845	<0.001**

**: p <.001

Table 6. Association between the socio-demographic characteristics of the nurses and knowledge, practice & attitude level at post – Intervention

Demographic characteristics	Poor Knowledge (n=13)		Fair Knowledge (n=13)		Good Knowledge (n=44)		Chi – Square p	Incompetent practice (n=16)		Competent practice (n=54)		Chi – Square p	Negative Attitude (n=17)		Positive Attitude (n=53)		Chi – Square p
	n	%	n	%	n	%		n	%	n	%		n	%	n	%	
Age (Years)																	
18 – 29	7	53.8	6	46.2	18	40.9	X^2 4.09	8	50.0	23	42.6	3.77	6	35.3	25	47.2	3.80
30 – 39	4	30.8	5	38.5	24	54.5	P= 0.393	5	31.3	28	51.9	P= 0.151	11	64.7	22	41.5	P=0.15
40 – 49	2	15.4	2	15.4	2	4.5		3	18.8	3	5.6		0	0.0	6	11.3	
Years of experience																	
< 5	13	100.0	9	69.2	9	20.5	X^2	14	87.5	17	31.5	16.03	11	64.7	20	37.7	20.53
5 – 10	0	0.0	3	23.1	6	13.6	34.22	1	6.3	8	14.8	P= 0.003*	6	35.3	3	5.7	P=<0.001**
10 – 15	0	0.0	1	7.7	19	43.2	P =	1	6.3	19	35.2		0	0.0	20	37.7	
15 – 20	0	0.0	0	0.0	8	18.2	<0.001**	0	0.0	8	14.8		0	0.0	8	15.1	
> 20	0	0.0	0	0.0	2	4.5		0	0.0	2	3.7		0	0.0	2	3.8	
Gender																	
Male	5	38.5	4	30.8	9	20.5	2.06	6	37.5	11	20.4	1.97	5	29.4	12	22.6	0.32
Female	8	61.5	9	69.2	36	81.8	P= 0.356	10	62.5	43	79.6	P= 0.160	12	70.6	41	77.4	P=0.571
Level of education																	
Diploma in Nursing	9	69.2	2	15.4	2	4.5	28.84 P=<0.001**	11	68.8	2	3.7	35.59 P= <0.001**	11	64.7	2	3.8	31.885 P=<0.001**
Bachelor's degree in nursing	4	30.8	8	61.5	28	63.6		5	31.3	35	64.8		5	29.4	35	66.0	
Master's degree in nursing	0	0.0	3	23.1	14	31.8		0	.0	17	31.5		1	5.9	16	30.2	
The department/unit you work for																	
PICU	2	15.4	1	7.7	7	15.9	1.72	3	18.8	7	13.0	3.480	3	17.6	7	13.2	2.36
NICU	4	30.8	3	23.1	13	29.5	P=0943	7	43.8	13	24.1	P= 0.32	6	35.3	14	26.4	P=0.501
SICU	5	38.5	5	38.5	13	29.5		3	18.8	20	37.0		3	17.6	20	37.7	
CCU	2	15.4	4	30.8	11	25.0		3	18.8	14	25.9		5	29.4	12	22.6	
Weekly working hours																	
Less than 35 hours	5	38.5	2	15.4	1	2.3	13.395 P= 0.009*	10	62.5	2	3.7	31.11 P=<0.001**	10	58.8	2	3.8	34.45 P= <0.001**
35 - 42 hours	4	30.8	5	38.5	18	40.9		4	25.0	19	35.2		7	41.2	16	30.2	
More than 42 hours	4	30.8	6	46.2	25	56.8		2	12.5	33	61.1		0	0.0	35	66.0	

**: p <.001

Table 7. Association between the nurses' alarm fatigue symptoms with their knowledge and practice level post – Intervention

	Improved a lot (n=28)		Needs improvement (n=39)		Not Improved (n=3)		Chi – Square	
	N	%	N	%	n	%	X^2	P
Knowledge Level							16.628	0.002*
Poor Knowledge	5	17.9	5	12.8	3	100.0		
Fair Knowledge	10	35.7	8	20.5	0	0.0		
Good Knowledge	13	46.4	26	66.7	0	0.0		
Attitude Level							21.194	<0.001**
Negative Attitude	0	0.0	14	35.9	3	100.0		
Positive Attitude	28	100.0	25	64.1	0	0.0		
Practice Level							10.69	0.004*
Incompetent	6	21.4	7	17.9	3	100.0		
Competent	22	78.6	32	82.1	0	0.0		

*: p<0.05; **: p<.001

Table 8. Correlation between the knowledge, practice, attitude level at post – Intervention

	Knowledge		Attitude		Practice	
	r	P	r	p	r	p
Knowledge	-	-	0.284	0.017	0.656	<0.001**
Attitude	0.284	0.017	-	-	0.261	0.029*
Practice	0.656	<0.001**	0.261	0.029*	-	-

*: p<0.05; **: p<.001

Discussion

The pediatric and neonatal intensive care units are equipped with various tools and equipment, such as monitors, mechanical ventilators, suction, incubators, infusion pumps, and other state-of-the-art devices. These are specifically designed to deliver and enhance care for critically ill infants and children. Each of these devices includes alarm systems that

alert pediatric critical care nurses to any issues or potential problems. Given the complex and constantly evolving nature of care in the intensive care unit, there is a heightened risk for errors. Clinical alarms play a vital role in notifying critical care nurses of potential threats or urgent situations involving critically ill pediatric patients. Managing and setting alarms in the NICU and PICU are key responsibilities of pediatric critical care nurses **(Sliman, et al.,2020)**. As a result, our study aims to assess the impact of implementing an educational intervention for pediatric critical care nurses to effectively manage alarm fatigue and improve patient care.

The current study showed that more than half of the studied nurses had bachelor degree of nursing. Additionally, more than two fifth of them (44.3%) were in the age group of 18- 29 years old with less than 5 years of experience. These results are in agreement with **Aysha, & Ahmed, (2019)** who studied the "effect of implementing clinical alarm nursing intervention program on nurses' knowledge, practice and patient outcomes at intensive care unit" at Tanta main university hospitals and reported that more than one-third of nurses aged between 20 to 30 years and had (2-10) years of experience in the ICU. As well, the current results showed that vast majority of them (92.9%) didn't receive any previous training on how to respond to alarms. Similarly, **Bach, et al. (2018), and Aysha, & Ahmed, (2019)** mentioned in their study that there is a lack of clinical alarm management educational intervention for nurses and they emphasize the importance of conducting alarm educational interventions for nurses before working on new equipment in intensive care units.

The current study found that after implementing the educational intervention program, study nurses' knowledge scores regarding clinical alarms and alarm fatigue significantly improved when compared to their pretest scores. This finding suggests that the researcher used effective teaching tools and learning resources to increase nurses' knowledge. Additionally, the results of this study showed that there was a statistically significant difference between the categories of knowledge held by nurses before and after the intervention program, showing improved knowledge following the program. This lack of training, the absence of standardized procedures for handling clinical alarm, and job pressure may all contribute to this low level of knowledge and understanding. In a similar study by **Lewandowska, et al. (2023)** entitled "Determining Factors of Alarm Fatigue among Nurses in Intensive Care Units—A Polish Pilot Study" on 400 Polish ICU nurses, the study revealed that nurses' ability to manage alerts from monitoring equipment is a key component in lowering alarm fatigue. Additionally, every nurse who took part in the study acknowledged that clinical alarms made them feel worried, but following the educational intervention, this number dropped to half. The study done by **Nyarko, et al. (2023)** suggests that education may be important for reducing alarm fatigue. Following alarm management training based on action planning theory, there has been evidence that alarm fatigue among ICU personnel has decreased.

Fatigue and desensitization can lead to nurses ignoring or not responding appropriately to alarms. In addition to the issue of false alarms, inadequate number of nurses and lack of training on alarm systems were also identified as barriers to clinical alarm management by more than half of nurses. This suggests that there may be a need for more staffing and education on alarm systems to ensure proper attention and response to alarms. This outcome was consistent with the findings of **Sendelbach et al. (2015)**, who said that numerous false alarms were the greatest challenge facing clinical alarm management and that these false alarms led to incorrect responses to serious alerts. Furthermore**, Lee et al. (2021)** noted in their study that false alarms and overreliance may be problems connected to patient circumstances and the proper alarm settings with relation to such situations. The study's findings highlight the importance of addressing these barriers in order to improve alarm management and patient safety. Strategies such as individualizing alarm ranges based on pediatric patient conditions and providing training on alarm systems can help reduce false alarms and improve nurses' ability to respond appropriately to alarms (**ERCI Institute, (2012) & Lee, et al. (2021)**.

Regarding nurses practice related to management of alarm system for the ventilator, infusion pump, proper skin preparation for ECG electrodes, Pulse oximetry monitor, incubators & cardiac monitor; it was found that the nurses had incompetent practice score level before implementation of educational intervention and they become highly significantly improved after implementation of educational intervention. Additionally, more than two thirds of studied nurses had incompetent practice in total score in pre intervention compared to quarter in post intervention and the difference was highly statistically significant. Similar results were reported by **Sliman, et al., (2020)** in their study entitled "the effect of alarm fatigue nursing management protocol on critical care nurses' experience" they reported in their study that the training protocol helps to increase the practice level of nurses and highly statistically significant improved ($p<0.001$) post protocol training **(Aysha, & Ahmed, (2019) and Casey, et al., (2018)**.

In summary, the current study found that there was a significant correlation between total knowledge and practice scores with educational level and years of experience. However, a previous study by **Aysha, & Ahmed, (2019)** did not find a significant relationship between nurses' knowledge and demographic characteristics such as age, clinical nursing experience, education, research participation, and training attendance. It is recommended for pediatric critical care nurses to receive ongoing training in monitoring systems and alarm settings to improve pediatric patient outcomes and prevent alarm fatigue.

Conclusion:

The alarm fatigue was considered a significant problem and health hazards for pediatric critical care nurses. The current study concluded that the majority of nurses suffered from severe symptoms of alarm fatigue before implementation of educational intervention and the severity of symptoms was reduced after implementation of educational intervention program. In addition, educational intervention seems to improve nurses' knowledge, practice regarding alarm system monitoring and management. This study highlights the positive impact of an educational intervention aimed at managing alarm fatigue in pediatric critical care units. By addressing alarm fatigue, nurses were better equipped to provide timely and effective care to critically ill pediatric patients. This intervention offers a promising approach to enhancing patient safety and improving the overall quality of care in pediatric critical care units.

Recommendations:

Based on the finding of the current study, the following are recommended:

1.Implement comprehensive educational interventions and provide resources for Continued Learning such as workshops, seminars, and online courses that allow pediatric critical care nurses to stay updated on best practices in alarm management and patient safety.

2.Ensure adequate staffing levels in pediatric critical care units to prevent nurses from becoming overwhelmed with alarm management. Overburdened nurses are more likely to experience alarm fatigue and may miss critical alarms. Implement strategies to distribute workload effectively and consider the impact of shift durations on alarm fatigue.

3.Establish regular reviews of alarm management protocols and policies based on feedback from pediatric critical care nurses. Continuously update guidelines to reflect best practices and emerging technologies in alarm system design and management.

4.Foster collaboration between nurses, physicians, biomedical engineers, and other healthcare professionals involved in patient care. Effective communication and interdisciplinary teamwork can lead to better alarm customization, improved response times, and reduced alarm fatigue.

5.Promote a culture of safety and accountability and encourage open discussions about alarm-related challenges, near misses, and incidents. Create a supportive environment that empowers nurses to escalate concerns and report instances of alarm-related issues.

6.Integrate advanced alarm filtering technology that can differentiate between false

alarms and clinically relevant alarms. Such technology can help reduce the overall number of alarms and provide nurses with more accurate and meaningful alerts.

By implementing these recommendations, healthcare institutions can make meaningful strides in reducing alarm fatigue and enhancing the clinical practices of pediatric critical care nurses, ultimately leading to improved patient care and outcomes.

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