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The Effect of Implementing Clinical Alarm Nursing Intervention Program on Nurses' Knowledge, Practice and Patient Outcomes at Intensive Care Unit

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Abstract Clinical alarms of medical devices in intensive care units considered a health technology hazard and one of the most essential methods that warn the critical care nurses for immediate or potential threats facing critically ill patients**.** ***The aim*** of the study was to evaluate the effect of implementing clinical alarm interventional program on nurses' knowledge, practice, and patient outcomes at intensive care unit. A quasi-experimental research design was utilized in this study. The study was conducted at post-anesthetic, and emergency intensive care unit Tanta University and Emergency Hospital. All critical care nurses working in the unit (40) and provide direct care with for ventilated patients were included in the study. Also, a convenience sample of 40 adults, mechanically ventilated patients divided into 2 groups 20 patients in each. Four tools were used for data collection ***Tool I*****:** A Structured Knowledge Questionnaire (pre-& posttest). ***Tool II***: Clinical Alarm Management Observational Checklist. ***Tool III:*** Nurses Perceptions of Alarm Fatigue pre and post Intervention Program. ***Tool (IV):*** "Patients assessment tool. ***The main results*** of this study revealed there were statistically significant differences between nurses' knowledge and practice categories indicating good knowledge and satisfactory practice after the intervention program, compared with poor knowledge and unsatisfactory practice level pre-intervention program where = (0.00). All nurses (100.0 %) agreed that they feel anxious due to clinical alarms compared to 50.0% of nurses who agreed on post-education. it was observed that 60% of patients in study group their weaning outcome were succeeded from the first attempt compared to 35% in control group. ***It was recommended that*** In-service training program should be conducted for nurses regarding alarm management and increase nurses' awareness of the presence of alarm fatigue.

Keywords: *alarm management, nurses' knowledge, nurses' performance, patient outcome, alarm fatigue*

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1. Introduction

Clinical alarms of medical devices in intensive care units were considered a health technology hazard and one of the foremost essential methods that warn the critical care nurses for immediate or potential threats facing critically ill patients before a catastrophic event occur. The effective management of clinical alarms proceeds to be a challenging area for critical care nurses in a different clinical setting with regard to how they are selected, set up, and responded to it. [1,2]

Clinical alarms management is considered a significant method in improving patient's outcomes and considered a National Patient Safety Goal (NPSG) according to the Joint Commission Accreditation of 2016. [2] This organization recommended that the hospitals should develop and implement policies and procedures associated with applicable alarm signals monitoring and management. [2,3,4]

Clinical alarms sources in the intensive care unit are generated from medical devices that includes not only cardiac physiological monitors for measuring vital signs but also therapeutic devices, such as mechanical ventilators, syringe or infusion pumps, air bed mattresses alarms, pneumatic compression devices and patient call systems. These devices have a variety of auditory and visual alarm signals that alert clinicians independently to changes in the condition of a patient. [3,4,5,6] Nevertheless, alarm sounds are not standardized among manufacturers, so critical care nurses need to be able to distinguish these audible alarms and react according to the perceived significance of the sound. [2,3]

Alarm categories include crisis alarm designed to detect life-threatening conditions, system failure to detect life-threatening device malfunction, warning alarm for detection of imminent danger, and advisory alarm to detect an unsafe situation. [4,5] Additionally, there are another alarm classification is based on clinical workflow consideration as false and nuisance alarms; that result from missing data caused by patient movement, broken

cables, and limitations in the device alarm detection algorithm. These types of alarm distract the attention of clinicians and are therefore a nuisance. [6] Also, intentional activities by trained bedside clinicians can generate non-actionable alarms, such as endotracheal suctioning of patient can trigger a ventilator alarm that does not require setting to be changed or modified. [5,6]

Excessive clinical alarms can cause an alarm hazard, that leads to inappropriate responses by clinicians to these alarms, such as ignoring, and disabling alarms without any action that may result in unsafe nursing practices and effects on patient's recovery and increase length of intensive care unit stay [7]. Also, excessive alarms and alarm noise results in stressful environment sleep deprivation, immune response impairment, cardiac arrhythmias, weaning failure, increased needs for pain and anxiety medications. [8,9]. Furthermore, alarm fatigue is one of the major hazards caused by false and non-actionable frequent alarms. It is a sensory overload occurs when critical care nurses in a clinical setting are overwhelmed by the extreme number of alarms, which can lead to alarm desensitization and delayed response to alarms which had a serious negative patient outcome [10-14].

The Critical-Care American Association has reported several strategies to reduce the number of false alarms [13]. These strategies include correct preparation of cardiac monitoring electrodes, daily change of electrodes, and customization of oxygen saturation via pulse oximetry machines. Identifies which alarm sounds, carefully turning patient on mechanical ventilation, ensure that the syringe pump is correctly positioned and secured [13].

Education and training on monitoring systems and devices alarms periodically for nurses, reducing response time to false alarms, helping in maintain patient's outcomes and prevent alarm fatigue [5,14]. Therefore, the present study aimed to evaluate the effect of implementing clinical alarm nursing intervention program on nurses' knowledge, practice and patient outcomes at intensive care unit.

2. Patients and Method

The aim of the study was:

1-To evaluate the effect of implementing clinical alarm nursing intervention program on nurses' knowledge, practice and patient outcomes at intensive care unit

2- To determine the effect of implementing clinical alarm nursing intervention program on nurses' perception of alarm fatigue

2.1. Research Hypothesis

- There is a significant difference between posttest knowledge scores to the pretest knowledge scores following implementation of clinical alarm nursing interventional program.

- There is a significant difference between posttest skill scores to the pretest skill scores following implementation of clinical alarm nursing interventional program.

- The study patients who managed by clinical alarm nursing intervention program will had improved outcome than control group

2.2. Operational Definitions

2.2.1. Patient's Outcome Includes

Decreasing presence of ECG abnormalities, weaning outcome were succeeded from the first attempt and decreased duration of mechanical ventilation in study group compared with control group.

2.2.2. Research Design

A quasi-experimental research design was utilized in this study.

2.2.3. Setting

This study was conducted at the ICUs of Tanta Main University hospital namely: Post anesthetics and Emergency intensive care unit, which receives patients with different disorders in the acute stage of illness. It consists of 15 beds it is equipped and well prepared for providing care for patients having life-threatening problems transferred from all hospital departments that include medical, surgical, and post-operation.

2.2.4. Subjects

The sample of this study was consisting of:

A) Patients:

A Purposive sample of 40 adults, mechanically ventilated patients of both sexes, fulfilling the inclusive criteria randomly divided into two groups as follows:

Group 1 (Control group) the pre-intervention group consisted of 20 adult mechanical ventilated patients received routine care of the intensive care unit. N.B Routine care of the ICU does not include any protocols or guidelines regarding clinical alarm management.

Group 2 Studied group (immediately post intervention group) this group was consisted of 20 adult mechanically ventilated patients, fulfilling the same inclusive criteria that receiving clinical alarm interventional program

The subjects of this study were select according to the following

Inclusions criteria:

- Adult patient from both sexes.
- Needs mechanical ventilation support more than 72 hours using any ventilator modes
- New admission, during the first 24 hours of intubation.

B) Nurses: all nurses (40) who were available during the period of data collection in the previously mentioned setting, had at least 6 months of working experience in ICUs and directly contact and caring with those ventilated patients.

2.3. Data Collection Tools

Four tools were developed by the researchers based on reviewing the relevant literature.

Tool I: A Structured Knowledge Nurses' Questionnaire (pre-& posttest) [4,5,10,12]. It was designed by the researcher in a simple Arabic language after reviewing the related literature to assess nurses' knowledge about clinical alarm management in ICU. Different types of

questions were used including open & closed-ended questions. It was divided into three parts:

Part (a): Sociodemographic characteristics of nurses such as gender, age, marital status, educational level, years of experience in ICU, and Previous attendance of training courses related to alarm management or alarm troubleshooting and policy or regulation inside the unit regarding alarm management.

Part (b): Nurses' knowledge regarding clinical alarm management (29 items). The tool's items were categorized under 6 main domains which were related to nurse's knowledge related to definitions and types of clinical alarms, cardiac monitor alarms, ventilator alarms (indicators and action taken regarding high and low flow alarms, syringe pump troubleshooting), pulse oximetry troubleshooting alarms and nurses' alarms fatigue.

Scoring system: Scoring system of the tool I: One score was allocated to each right answer and zero to the wrong answer. The total score of nurses' knowledge was calculated and classified as follows: 75% and more were considered good, 74-60 % was considered fair, and less than 60% was considered poor.

Part (c): Nurses perception according to barriers facing them for clinical alarm management pre and post-intervention program [8]. This tool was adopted from the Healthcare Technology Foundation (HTF) to assess nurses' perceptions toward barriers facing them for clinical alarm management pre and post-intervention, it includes (9 items)

Scoring system

It consisted of 9 items on a 5-point scale: from 1, meaning 'strongly disagree', to 5, meaning 'strongly agree'

Tool II: Clinical Alarm Management Observational Checklist [10,11,12].

This tool was developed by the researcher after reviewing the related literature to evaluate nurses' practice toward clinical alarm management. It covered 8 main domains with 50 sub-items related to electrode placement and proper skin preparation, modify the alarm limits according to patient's condition, ventilator Troubleshooting alarms management, false high-rate alarm management, weak signal alarm management, baseline (no wave-form) management, Pulse oximetry alarms management and syringe pump alarm management.

2.5. Scoring System for Nurses' Skills

Every step was evaluated as follows; correctly done was scored (2), incorrectly done was scored (1) and not done was scored (0). The total score of nurses' skills was calculated and classified as follows: scores of <65% was considered unsatisfactory and scores of ≥ 65% was considered satisfactory.

Tool III: Nurses Perceptions of Alarm Fatigue pre and post Interventional Program [16,17]. It was adopted from Japanese Occupational Hygiene Association in 2002 [16] and from the instrument applied by Kim and Sung [17]. It assess nurses perceptions regarding alarm fatigue and covered 6 items related to nuisance alarms occur frequently in intensive care units, I feel anxious due to clinical alarms, I sometimes silence patient's alarm in the ICU without responding to the patients' condition, I have become desensitized to the sound of alarms in ICU, alarm fatigue occurs frequently in ICU and alarm fatigue had negative effect on patient safety.

Scoring system: It consisted of 6 items, fatigue was measured using a 5-point scale using a 1-5 scale with 1= Strongly disagree, 2= Disagree, 3= Neither Agree or Disagree, 4= Agree, 5= Strongly Agree.

Tool (IV): **''Patients assessment tool** [10,11,14]. This tool was developed by the researcher after reviewing the relevant literature, it comprised 2 parts:

Part (a):* patients' Sociodemographic and medical clinical baseline data*: It revealed data about patient's age, sex, referred from another unit in the hospital, smoking history, past, and current medical history. Previous hospital (Last admission since), and artificial airway intubation

Part (b): Effect of Clinical Alarm Nursing Intervention Program on Patient Outcome. This tool evaluated the effect of clinical alarm management program on patient outcome and consisted of 5 items related to Ventricular Fibrillation (VF), Ventricular Tachycardia (VT), hypoxia (decreased So_2), weaning outcomes and duration of mechanical ventilation.

Scoring systems

Each present item was given one score and not present item was given (0) score, duration of mechanical ventilation will be summed up and converted into mean and stander deviation.

3. Method

1-Administrative process:

The study was conducted on three phases (preparatory phase, implementation phase, and evaluation phase).

Preparatory phase included:

- Written approval to conduct the study was obtained from the responsible authority of Emergency Anesthetic ICU before conducting this study through official letters from the faculty of nursing explaining the purpose of the study.

Informed consent:

-Patient's informed consent was obtained from patients and /or their families if the patients were unconscious after an explanation of the purpose of this study to participate in the study, confidentiality will be assured.

-Nurse's informed consent to participate in the study was obtained after the researcher explained to the nurses the objectives of the study.

- Tools used in this study was developed in English and translated to Arabic by the researcher based on reviewing the relevant literature. [9-17]

Ethical consideration:

- The anonymity and confidentiality of responses of patients and the nurses, voluntary participation and right to refuse to participate in the study were emphasized to subjects.
- The researcher explained to the nurses that they have the right to withdraw when they want without any constraints
- The nurses informed that they could withdraw from the study at any time without any constraints.

Content validity:

- The tools of the study were tested for content validity by nine jury experts in the field of medical-surgical nursing, critical care nursing, anesthesiologists and medical biostatistics. Modifications were carried out accordingly.

A pilot study:

- A pilot study was conducted on five nurses and five patients to test the feasibility and applicability of the tool and the necessary modification was done.

- The reliability test for tool one (knowledge assessment tool), tool two (skills assessment tool) and tool three (nurses' fatigue) by using Cronbach's coefficient alpha (r=0.820, 0.830 and 0.790 respectively)

- Development of the intervention program was developed by the researcher, after reviewing the relevant literature.The following steps were adopted to develop the program.

- Stating the program general and specific objectives.

The overall objective of the developed educational program to improve the critical care nurses' knowledge and skills about clinical alarm management .

Planning the intervention program: the content of the program was arranged into four teaching sessions in addition to preliminary one. The content of the program covered two parts related to Knowledge about clinical alarm management, Performance of procedure required for clinical alarm management.

-Theoretical Part Included:

- Definitions and types of clinical alarms
- Levels of clinical alarm related to cardiac monitor alarms, causes of weak signal and baseline (no waveform)
- Ways to reduce false alarms
- Nurses knowledge regarding ventilator alarms
- Nurses knowledge regarding Syringe pump troubleshooting
- Nurses knowledge regarding Pulse oximetry troubleshooting
- Measures of prevention of alarm fatigue

-Practical Part Included procedure about :

- Electrode placement and proper skin preparation
- Modify the alarm limits according to the patient's condition
- Artifact alarm management
- False high-rate alarm management
- Weak signal alarm management
- Baseline (no waveform) management
- Ventilator troubleshooting alarms
- Pulse oxy meter troubleshooting (alarms)
- Syringe pump troubleshooting alarm

Learning Environment: The program was conducted in the head nurse's office at the hospital. Teaching methods included lectures and discussion by using audiovisual aids: - Power Point presentation, videos, and booklet developed by the researcher based on reviewing the related literature. Demonstration and re-demonstration were done in ICU.

- The total sample was divided into 8 subgroups included five nurses each session for better performance and understanding.

Implementation phase and evaluation phase: - all nurses were interviewed during break time (one hour) in different shifts or before the beginning of the shift. - Assessment of knowledge was done twice as follows: - pretest assessment before giving intervention program and as baseline data for later comparison with a future posttest.

-The second administration of the questionnaire was carried out after the implementation of the intervention program to identify its effect on nurses' knowledge.

- Assess nurses' practice: The researcher observes the nurses' skills using observational checklist tool twice before and immediately after program implementation.

Implementation of the program:

- The program was implemented for the 8 subgroups of nurses. All groups were exposed to five session's in addition to the preliminary one; every session duration was 30 minutes. Preliminary session: In this session, the researcher met the participants and explained the objectives, contents, and methods of evaluation of the program.
- Session I included: definitions and types of clinical alarms, levels of clinical alarm related to cardiac monitor alarms, causes of weak signal and baseline (no waveform) alarm.
- Session II included: ventilator trouble shouting alarms as high pressure, low (exhaled) tidal volume, low (inspiratory) pressure and Apnea alarm.
- Session III included: Types and causes of syringe pump troubleshooting and Pulse oximetry troubleshooting alarm.
- Session IV included: ways to reduce false alarms, definition, causes, measures of prevention of alarm fatigue and the researcher summarized and emphasized the important points
- Session V included clinical alarm management procedure demonstration and re-demonstration was performed by a researcher for duration of 1 hour.
- Group discussion was encouraged with continuous feedback to ensure understanding and achievement of the specific objective of the program. Each nurse demonstrates and re-demonstrates the steps individually and completely performed the steps.

Evaluation of program: The evaluation of the program was carried out immediately after the application of the program using tools one, two, three and four in order to test the effectiveness of the program on nurses' knowledge, performance, nurse's fatigue, and patient outcome. Data was collected by the researcher for approximately eight months starting from January 2018 to the end of August 2018.

3.1. Limitation of the Study

1-Lack of Egyptian statistical record about clinical alarm management.

2-Limited number of patients.

3.2. Statistical Analysis

- The data entry and data analysis were done using (SPSS Ver.19.).
- Descriptive statistics (number, percentage, mean and standard deviation) were done.
- Chi-square test was done to compare qualitative variables between before and after group.

- P-value considered statistically significant when p< 0.05.

4. Results

Table 1 represents distribution of the studied nurses regarding socio-demographic characteristics. Regarding age, more than half of nurses (57.5%) had age ranged from (20- <35) and had Technical Institute degree. The majority of them (75%) were married and mean duration of their experiences in ICU were 5.45±3.501 years. All nurses (100%) had no in-service training courses related to alarm management or alarm troubleshooting and there wasn't any policy or regulation inside the unit regarding alarm management.

Table 2: Distributions of studied nurses regarding knowledge domains of clinical alarm management pre and post-interventional program. This table showed that the mean knowledge scores of nurses in relation to definitions, types of clinical alarms, cardiac monitor alarms, ventilator alarms, syringe pump troubleshoot, Pulse oximetry troubleshooting, and alarm fatigue were increased immediately after the nursing intervention program than the pre-intervention program with significant statistical differences were observed where P<0.05.

Table 3 illustrated distribution of the studied nurses according to barriers facing nurses for clinical alarm management pre and post-intervention, it was found that all nurses (100%) agreed that frequent false alarm decreased attention to alarm and insufficient knowledge about interpretation of alarm considered as barriers for clinical alarm management before intervention program versus to (37% and 15% respectively) post program with significant difference before and after intervention program p = **0.00**, Also the majority of nurses (95%, 87.5% and 87.5% respectively) agreed that high patient -to- nurse ratio, inability to hear an alarm and difficulty in distinguishing the alarms and responding to them properly considered as barriers for clinical alarm management before intervention program, while this percentage decreased significantly after application of intervention program where p = (**0.00**) respectively.

Table 1. Distribution of the studied nurses regarding socio-demographic characteristics

Characteristics	The studied nurses (n=40)	
	N	%
Age (in years)		
• 20-<30	23	57.5
• 30-<40	17	42.5
Married	10	25
Single	30	75
Married		
Educational level		
• Technical Institute	23	57.5
• Baccalaureate	17	42.5
Experience in ICU (in years)		
Range	**(2-12)**	
Mean ± SD	**5.45±3.501**	
Previous in-service training courses related to alarm management or alarm troubleshooting		
• No	40	100.0
policy or regulation inside the unit regarding alarm management		
• No	40	100.0

Table 2. Distributions of studied nurses regarding knowledge domains of clinical alarm management pre and post-interventional program

Knowledge domains	The studied nurses (n=40) Range Mean ± SD		t P
	Pre	Post	
A-Nurses knowledge related to definitions and types of clinical alarms	(0-3) 1.98±1.097	(0-3) 2.63±0.952	**2.829 0.006***
B-Nurses knowledge related to cardiac monitor alarms	(0-6) 2.53±1.617	(4-9) 6.60±1.336	**12.287 0.00***
C-Nurses knowledge regarding ventilator alarms	(0-6) 2.48±2.309	(3-7) 5.55±1.131	**7.563 0.00***
D- Nurses knowledge regarding Syringe pump troubleshooting	(0-2) 0.85±0.893	(0-4) 3.25±0.981	**11.445 0.00***
E- Nurses knowledge regarding Pulse oximetry troubleshooting	(0-3) 1.73±1.012	(1-3) 2.70±0.564	**5.321 0.00***
F- Nurses knowledge regarding Alarms fatigue.	(0-3) 1.43±1.035	(1-3) 2.50±0.641	**5.586 0.00***

* Significance at level P < 0.05.

Table 3. Distribution of the studied nurses according to barriers facing nurses for clinical alarm management pre and post-intervention

Barriers facing nurses for clinical alarm management	The studied nurses (n=40)								χ^2 P
	Pre				Post				
	Disagree		Agree		Disagree		Agree		
	N	%	N	%	N	%	N	%	
1. Frequent false alarm decreased attention to alarm	0	0.0	40	100.0	25	62.5	15	37.5	**FE 0.00***
2. Insufficient knowledge about interpretation of alarm	0	0.0	40	100.0	34	85.0	6	15.0	**FE 0.00***
3. Inappropriate staffing numbers per shift	40	100.0	0	0.0	40	100.0	0	0.0	-
4. High patient -to- nurse ratio	2	5.0	38	95.0	2	5.0	38	95.0	0.00 1.00
5. Inability to hear an alarm	5	12.5	35	87.5	37	92.5	3	7.5	**FE 0.00***
6. Difficulty distinguishing the alarms and responding to them properly	5	12.5	35	87.5	37	92.5	3	7.5	**FE 0.00***
7. Overload of noise experienced by care teams	23	57.5	17	42.5	27	67.5	13	32.5	FE 0.489
8. There's not enough time to manage a large number of alarms?	17	42.5	23	57.5	38	95.0	2	5.0	**FE 0.00***
9. Devices not configured to minimize nuisance alarms	19	47.5	21	52.5	39	97.5	1	2.5	**FE 0.00***

* Significance at level P < 0.05.

Table 4. Distribution of studied nurses in relation to mean scores of practice domains of clinical alarm management pre and post-intervention program

A total score of domains	The studied nurses (n=40) Range Mean ± SD		t P
	Pre	Post	
A. Electrode placement and proper skin preparation	(0-4) 3.03±0.92	(4-8) 6.33±1.35	**12.80 0.00***
B. Modify the alarm limits according to the patient's condition	(0-0) 0.00±0.00	(0-1) 0.53±0.51	**6.57 0.00***
C. Ventilator Troubleshooting Alarms management	(0-4) 2.70±1.42	(0-4) 3.55±0.96	**3.14 0.002***
D. False high-rate alarm management	(0-1) 0.25±0.44	(0-3) 1.63±1.17	**6.96 0.00***
E. Weak signal alarm management	(0-3) 1.28±0.88	(1-4) 3.25±0.78	**10.67 0.00***
F. Baseline (no waveform) management	(0-4) 2.40±1.39	(1-4) 3.45±1.11	**3.73 0.00***
G. Pulse oximetry alarms management	(1-4) 1.75±1.01	(1-4) 3.68±0.73	**9.793 0.000***
H. Syringe pumps alarm management	(1-5) 3.60±1.39	(2-5) 4.50±0.82	**3.527 0.001***
Total practice score	(6-14) 9.65±2.70	(13-23) 18.73±2.69	**15.05 0.00***

* Significance at level P < 0.05.

Table 4 clarifies distribution of studied nurses in relation to mean scores of practice domains of clinical alarm management pre and post-intervention program. In this table, there was a statistically significant improvement of nurse's practice domains post-intervention program regarding electrode placement and proper skin preparation, modify the alarm limits according to patient's condition, ventilator alarm artifact management, false high-rate alarm management, weak signal alarm management and baseline (no waveform) management, Pulse oximetry alarms and syringe pumps alarm management) as P value <0.05.

In addition, there was a statistically significant difference existed between the mean nurse's performance score pre and post interventions program the total mean practices score was **9.65±2.70** before the program and increased to **18.73±2.69** immediately after the program.

Table 5 illustrates Percent distribution of the studied nurses according to their total level of knowledge related to clinical alarm management pre and post-intervention program. It was observed that there were statistically significant differences between nurses' knowledge categories indicating good knowledge after the intervention program, compared with poor knowledge before an intervention program where = (**0.00**).

Table 6 illustrates Percent distribution of the studied nurses according to their total level of practice of clinical alarm management pre and post-intervention. It was observed that there were statistically significant differences between nurses' practice categories indicating satisfactory practice level post-intervention program, compared with unsatisfactory practice level pre-intervention program where = (**0.00**).

Table 5. Percent distribution of the studied nurses according to their total level of knowledge related to clinical alarm management pre and post-intervention program

Total knowledge level	The studied nurses (n=40)				χ^2 P
	Pre		Post		
	N	%	N	%	
• Poor	32	80.0	1	2.5	**59.18 0.00***
• Fair	8	20.0	9	22.5	
• Good	0	0.0	30	75.0	
Range Mean ± SD	**(0-21) 10.98±5.376**		**(17-28) 23.23±2.769**		**t=12.813 P=0.00***

* Significance at level P < 0.05.

Table 6. Percent distribution of the studied nurses according to their total level of practice of clinical alarm management pre and post-intervention

Total Practice level	The studied nurses (n=40)				χ^2 P
	Pre		Post		
	N	%	N	%	
• Unsatisfactory	40	100.0	7	17.5	**FE 0.00***
• Satisfactory	0	0.0	33	82.5	

<65% unsatisfactory, ≥65% Satisfactory
* Significance at level P < 0.05.

Table 7. Comparison between nurses' age and their total level of knowledge related to clinical alarm management pre and post-intervention program

Characteristics	The studied nurses (n=40) Total knowledge level											
	Pre				χ^2 P	Post						χ^2 P
	Poor		Fair			Poor		Fair		Good		
	N	%	N	%		N	%	N	%	N	%	
Age												
• 20-<30	21	52.5	2	5.0	**FE**	0	0.0	3	7.5	20	50.0	4.535
• 30-<40	11	27.5	6	15.0	**0.045***	1	2.5	6	15.0	10	25.0	0.104

* Significance at level P < 0.05.

Table 8. Represents a correlation between total knowledge and practice scores with age and level of experience pre and post-intervention program

Nurses' characteristics	Total knowledge score				Total practice score			
	Pre		Post		Pre		Post	
	r	P	r	P	r	P	r	P
Age (in years)	0.110	0.500	-0.124	0.446	**0.706**	**0.000****	0.292	0.068
Years of experience	0.167	0.302	-0.085	0.602	**0.445**	**0.004****	0.012	0.939

* Significance at level P < 0.05
** Highly significance at level P < 0.01.

Table 9. Percent distribution of the studied nurses regarding perceptions of alarm fatigue pre and post-intervention program

Fatigue symptoms	The studied nurses (n=40)								χ^2 P
	Pre				Post				
	Disagree		Agree		Disagree		Agree		
	N	%	N	%	N	%	N	%	
1. Nuisance alarms occur frequently in intensive care units	7	17.5	33	82.5	28	70.0	12	30.0	**FE 0.00***
2. I feel anxious due to clinical alarms	0	0.0	40	100.0	20	50.0	20	50.0	**FE 0.00***
3. I sometimes silence patient's alarm in the ICU without responding to the patients' condition	11	27.5	29	72.5	26	65.0	14	35.0	**FE 0.002***
4. I have become desensitized to the sound of alarms in ICU	10	25.0	30	75.0	24	60.0	16	40.0	**FE 0.003***
5. Alarm fatigue occurs frequently in ICU	21	52.5	19	47.5	9	22.5	31	77.5	**FE 0.010***
6. Alarm fatigue had a negative effect on patient safety	29	72.5	11	27.5	4	10.0	36	90.0	**FE 0.00***

* Significance at level P < 0.05.

Table 7 shows a comparison between nurses' age and their total level of knowledge related to clinical alarm management pre and post-intervention program. It was found that more than half of nurses (52.5%) who were in ages between 20-<30 had poor knowledge score pre-intervention program while 50% of them had good knowledge score post-intervention program. On the other hand, a minority of nurses (25%) who in ages between 30-<40 had good knowledge score after the intervention.

Table 8 represents a correlation between total knowledge and practice scores with age and level of experience pre and post-intervention program. There was no statistically significant correlation between nurses' total knowledge and practice score with age, and years of experience at pre and post-intervention program where $p > 0.05$.

Table 9 show distribution of the studied nurses about perceptions of alarm fatigue pre and post-intervention program, Majority of nurses (82.5%) agreed that nuisance alarms occur frequently in intensive care units prior to the education compared to 30.0% of nurses that agreed with post-intervention program. All nurses (100.0 %) agreed that they feel anxious due to clinical alarms compared to 50.0% of nurses who agreed on post-intervention program.

Majority of nurses (72.5% and 75.0%) agreed that they sometimes silence patient's alarm in the ICU without responding to the patients' condition and they have become desensitized to the sound of alarms in ICU pre-education program compared to 35.0% and 40% post-intervention program, respectively.

However only 47.5% and 27.5% of nurses agreed that alarm fatigue occurs frequently in ICU and Alarm fatigue had negative effect on patient safety prior education program compared to 77.5% and 90.0% post-intervention program, respectively.

5. Patients

Table 10 illustrates the distribution of the studied patients' control group (pre-intervention group and study group (post-intervention group), according to their socio-demographic characteristics and medical characteristics data. there was no statistically significant difference between two groups in relation to in relation to their socio-demographic characteristics and medical characteristics data $P > 0.05$. It was observed that nearly more than one third 45% and 30% of control and study group had age between 40-<50 years.

In addition, it was observed that nearly half (55% and 50%%) of the control and study subjects had a head injury and respiratory disorders respectively as a common diagnosis among both groups. regarding artificial airway it was observed that more than two third (60% and 75%) of patient in control and study group had endotracheal tube intubation.

Table 10. Distribution of the studied patients according to their socio-demographic characteristics and medical characteristics data

Characteristics	The studied patients (n=40)				χ^2 P
	Control group (n=20)		Study group (n=20)		
	N	%	N	%	
Age (in years)					
• 20-<30	8	40.0	8	40.0	1.60 0.449
• 30-<40	3	15.0	6	30.0	
• 40-<50	9	45.0	6	30.0	
Sex					
• Male	12	60.0	10	50.0	FE 0.751
• Female	8	40.0	10	50.0	
Referred from another unit in the hospital					
• Medical ICU	2	10.0	1	5.0	1.03 0.598
• Postoperative	8	40.0	11	55.0	
• Emergency	10	50.0	8	40.0	
Smoking					
• Smoker	3	15.0	7	35.0	FE 0.273
• Non-smoker	17	85.0	13	65.0	
Previous hospital (Last admission since)					
• No	16	80.0	12	60.0	FE 0.301
• yes	4	20.0	8	40.0	
# **Current medical history: Diagnosis**					
• Cardiovascular disorders	0	0.0	0	0.0	
• Respiratory tract disorder	9	45.0	10	50.0	FE 0.748
• Head injury	11	55.0	10	50.0	
• Renal system insufficiency	7	35.0	9	45.0	
Artificial airway intubation					
• Endotracheal	12	60.0	15	75.0	FE 0.523
• Tracheostomy	10	50.0	7	35.0	

* Significance at level $P < 0.05$.

Table 11. Distribution of studies groups according to effect of clinical alarm management program on patient outcome

Clinical data	The studied patients (n=40)				χ^2 P
	Control group (n=20)		Study group (n=20)		
	N	%	N	%	
ECG abnormalities					
Ventricular Fibrillation (VF)	12	60.0	4	20.0	**FE 0.022***
Ventricular Tachycardia (VT)	13	65.0	8	40.0	FE 0.205
Hypoxia (decreased so_2)	11	55.0	11	55.0	FE 1.00
Weaning outcomes					
Succeeded	7	35.0	12	60.0	FE 0.205
Failed and patient a synchronized	13	65.0	8	40.0	
Duration of mechanical ventilation	(15-30) 22.25±5.49		(15-20) 18.25±2.45		**t=2.974 P=0.005***

More than one answer was chosen.
* Significance at level P < 0.05.

Distribution of studies groups according to effect of clinical alarm management program on patient outcome, in relation to ECG abnormalities, it was found that minority (20% and 40% respectively) of patients in study group had ventricular fibrillation and tachycardia compared to (60% and 65%) in control group. Regarding weaning outcome, it was observed that 60% of patients in study group their weaning outcome were succeeded from the first attempt compared to 35% in control group. In relation to duration of mechanical ventilation it was observed decreased mean and standard deviation duration of mechanical ventilation (18.25±2.45) in study group compared with 22.25±5.49 in control group.

6. Discussion

Clinical alarms sounds are an important component of most machines in critical care unit as they alert nurses about changing in the condition of patients. Therefore, it is important that nurses should had good knowledge and satisfactory skills about managing clinical alarms. [18] Based on the results of the present finding, it was found that more than half of nurses had age ranged from (20-<35), had a technical institute degree and were married. This result was consistent with the result of Shahin et al (2012) [19] in Al-Manial university Hospital in Egypt who found that more than one-third of nurses' age was ranged between 25>34 years and more than half of them were diploma nurses.

Also, the present finding showed that all nurses in this study had no in-service training courses related to clinical alarm management or alarm troubleshooting and there wasn't any policy or regulation inside the unit regarding alarm management. This indicates that nurses are not prepared before graduation and the experiences of the nurses have been gained while working only in an intensive care unit. Therefore, in-service training program is necessary to prepare nurses to handle clinical alarm management at the postgraduate level. In the same line, Whalen (2014) [20], Lacker (2011) [21] and Bach (2018) [22] mentioned that there was a lack of in-service training program about clinical alarm management for nurses and they focused on the importance to conduct alarm training programs for nurses prior to working on new devices in intensive care units.

Regarding mean knowledge score of all subtotal knowledge items of definitions, types of clinical alarms, cardiac monitor, ventilator alarms, Infusion and feeding pump troubleshooting, Pulse oximetry troubleshooting and alarm fatigue, the present study showed a significant improvement of knowledge scores among studied nurses immediately after the nursing intervention program compared with their pretest score. This is interpreted that the researcher had suitable learning media and material for teaching that improved nurses' knowledge. Also, the present finding revealed that there was a statistically significant difference between nurses' knowledge categories indicating good knowledge after the intervention program compared with poor knowledge before the intervention program. This low level of knowledge may be related to lack of training sessions, no standard guidelines for managing clinical alarm, work overload, lack of the desire of nurses to improve their knowledge, especially those who have been working in ICUs for several years.

This finding was consistent with Meng'anyia *e*t al., (2017) [23] who reported that poor level of knowledge of nurses on clinical alarm management and effective training on clinical alarm management is needed. Similarly, Gazarian (2015) [24] and Sowan et al (2015)(25) documented that nurses are not familiar with the complexities of monitoring equipment and stressed that there is an immediate need to improve nursing education in the use of ECG monitoring and alarm management.

As regard barriers facing nurses for clinical alarm management, the present finding revealed that all nurses agreed that frequent false alarm decreased attention to alarm and insufficient knowledge about interpretation of alarm considered as barriers for clinical alarm management before intervention program while this percentage decreased significantly after application of intervention program. This may be attributed to that nurses who overexposed to excessive and false alarms may become less sensitive, careless, experience a decrease in

concentration and commit mistakes. This result agreed with Sendelbach et al (2016) [26] they reported that the most barriers facing clinical alarm management was frequent false alarms which cause them to cope improperly with significant alarms. Also, ERCI Institute (2012) [27] stated that the frequency of false alarms may be reduced if critical care nurses took into account the current conditions of patients and set alarm ranges individualized.

Also, the present finding revealed that the majority of nurses agreed that high patient -to- nurse ratio, inability to hear an alarm and difficulty in distinguishing the alarms and responding to them properly considered as barriers for clinical alarm management before intervention program, while this percentage decreased significantly after application of intervention program. This may be attributed to the effect of the intervention program improved nurse's awareness about alarm management. This result was in line with Edworthy et al., (2006) [28] they reported that majority of nurses can't distinguishing different types of alarms from others as every device had a different alarms type. Also, *Meng'anyia* et al., (2017) [23] mentioned that high patient to nurse ratio considered as workload for nurses and barriers for clinical alarm management.

Concerning distribution of studied nurses in relation to mean scores of practice domains of clinical alarm management pre and post-intervention program. The present finding revealed improved total mean practices score domains of (electrode placement and proper skin preparation, modify the alarm limits according to patient's condition, ventilator alarm artifact management, false high-rate alarm management, weak signal alarm management and baseline (no waveform) management after application of interventional program than before program application. This may be due that clinical alarm management has not been included in the nursing curriculum and the educational program refreshes knowledge of nurses, which in turn leads to improved practice. This finding was agreed with Thompson and Stapley (2011) [29] they emphasized that the educational program helps to improve and develop the skills and knowledge of nurses and found wide differences between pre-posttests. Similarly, Lansdowne et al., (2016) [30] reported that education critical care nurses about change in default alarm parameters lead to a reduction in false alarms in a CCU setting and improved patients' parameters.

Furthermore, the present finding showed that all studied nurses' practice levels were in an unsatisfactory level preprograms intervention and the majority of them had satisfactory level after program intervention. The unsatisfactory level of practice may be related to low knowledge level about alarm management, an increase in the number of patients and workload. In this respect, Cvach (2012) [31] emphasized that increased workload complexity leads to deteriorations of alarm response and task performance and educational program about clinical alarm management helps to improve the skills and knowledge of nurses.

Regarding a comparison between nurses' age and their total level of knowledge. It was found that more than half of nurses who were in ages between 20-<30 had poor knowledge score pre-intervention program while fifty percent of them had good knowledge score post-intervention program. On the other hand, minority of nurses who in ages between 30<40 had good knowledge score after the intervention. Poor knowledge may be due to that clinical alarm management not included in pre-graduated courses and lack of hospital policy and in-service training program about clinical alarm management. Also, young nurses may have a desire to refresh her knowledge than old nurses. This finding was reinforced by *Meng'anyia* et al., (2017) [30] who confirmed that most nurses who had age between 25-35 years had the highest scores in alarm management.

Regarding the correlation between total knowledge and practice scores with age and level of experience pre and post-intervention program, the present finding revealed that there was no statistically significant correlation between nurses' total knowledge and practice score with age, and years of experience at pre and post-intervention program. This finding was supported by Qaddumi & Khawaldeh (2014) [32] who revealed no significant relationship between nurses' knowledge and their age, clinical nursing experience, education, research participation, and attendance of training. Similarly, Taha and Ali, (2013) [33] reported that nurses' age and years of experience had no significant influence on knowledge and practice scores.

Regarding the distribution of the studied nurse's perceptions of alarm fatigue pre and post-intervention, the present result indicating that majority of nurses agreed that nuisance alarms occur frequently in intensive care units prior to the intervention compared to one-third of nurses that agreed on the post-intervention program. All nurses agreed that they feel anxious due to clinical alarms compared to fifty percent of nurses who agreed on post-intervention program. This indicates that majority of nurses became aware of the existence of alarm fatigue in the post-intervention program than the pre-intervention program suggesting that the education succeeded in making staff aware of the problem of alarm fatigue in the ICU. Similarly, Graham and *Cvach* (2010) [34] showed that majority of nurses agreed that "nuisance" alarms occur frequently leading anxious feeling, disrupt patient care, and can reduce trust in alarms and causing clinicians to disable them. Also, *Ryherd et al.*, (2008) [35] found that excessive alarms in ICU can contribute to symptoms of stress amongst clinical staff including fatigue, a problem with concentration, and headaches.

Additionally, the present finding revealed that most nurses agreed that they sometimes silence patient's alarm in the ICU without responding to the patients' condition and they become desensitized to the sound of alarms in ICU pre-intervention program however this percentage decreased post-intervention program. This may be attributed to lack of training of nurses on alarm management and frequent false alarms reducing attention and response to alarms that occur, all contribute to the problem of alarm fatigue preprogram intervention, however, nurses became aware of the existence of alarm fatigue in the post- intervention program and their response to clinical alarm was improved than pre- intervention program. This finding was in accordance with the Oliveira et al (2018) [36] who recommended that nurses' education on clinical alarm and alarm fatigue risk

has been successful in raising awareness of the alarm fatigue problem in the ICU.

However, the majority of nurses agreed that alarm fatigue occurs frequently in ICU and alarm fatigue had a negative effect on patient safety post education program. This attributed to those nurses became aware of the existence of alarm fatigue in ICU post educational program and become aware of its effect on patient safety. This result is similar to Casey (2018) [37] and Lee [38] reported that alarm fatigue had serious effects on patient safety and outcomes.

As regard to percent distribution of the studied patients according to their socio-demographic characteristics and medical characteristics data. The present results showed that no statistically significant difference was found between two groups in relation socio-demographic characteristics and medical characteristics It was observed that nearly more than one third of control and study group had age between 40-<50 years. This result was in congruent with Sayed et al (2017) [39] they reported that the majority of studied critically ill patients were at this age and there's no significant difference between two groups in relation to socio-demographic.

Also, the present finding showed that more than two third of patient in control and study group had endotracheal tube intubation and nearly half of the control and study subjects had a head injury and respiratory tract disorders as a common diagnosis among both groups. That may be attributes that males were more affected with head injury than females and this diagnosis may require most of the patient attached to mechanical ventilation. This result was consistent with Shamali et al (2016) [40] they found that the majority of critically ill patients had head injury and respiratory tract disorders as a common diagnosis and attached to mechanical ventilations.

In relation to the distribution of studies groups according to the effect of clinical alarm management program on patient outcome, the present finding revealed that minority of patient in the study group had ventricular fibrillation and tachycardia compared to more than two third of patients in control group. Regarding weaning outcome, it was observed that more than two third of patients in the study group their weaning outcome were succeeded from the first attempt compared to a one-third patient in the control group. In addition, the present finding revealed decreased duration of mechanical ventilation in the study group compared to the control group. This may be attributed to that the educational program had increased nurse's responsiveness to alarms and create a suitable care and environment for patients. In this regard Hensley (2018) [41] and Xie (2009) [42] reported that the performance of staff is likely to be compromised by high rates of false and non-actual alarms that directly affect patient outcomes. Importantly, it has been shown that the excessive alarm delays patient recovery, increases stay length, and negatively influences patient satisfaction.

7. Conclusions

-It was concluded that there were statistically significant differences between nurses' knowledge and practices categories indicating good knowledge and satisfactory practice after the nursing intervention program, compared with poor knowledge and unsatisfactory practice pre-intervention program.

-All nurses agreed that they feel anxious due to clinical alarms compared to fifty percent of nurses who agreed on post- intervention program and there was a significant difference among nurses' perceptions regarding alarm fatigue pre and post-intervention.

-weaning outcome were succeeded from the first attempt in study group and the duration of mechanical ventilation was decreased in the study group compared to the control group.

According to the concluded findings, the current study recommends the following:

- In-service training program should be conducted for nurses regarding alarm management and increase nurses' awareness of the presence of alarm fatigue
- This program should be implemented in similar setting for confirmation of the results.

Further research is proposed to examine the effect of the implementation of this program on decreasing complications of patients in ICU.

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