Assiut Scientific Nursing Journal
http://asnj.journals.ekb.eg http://www.arabimpactfactor.com
DOI: 10.21608/asnj.2023.227191.1649 http://olddrji.lbp.world/indexedJournals.aspx
https://vlibrary.emro.who.int/journals/assiut-scientific-nursing-journal

Effect of implementing noise reduction interventions on sound levels and alarm fatigue in intensive care units

Intessar Mohamed Ahmad[1] & Samar Abdel Razek Younes[2]
[1.] Assistant Professor of Critical Care and Emergency Nursing, Faculty of Nursing, Damanhour University, Egypt.
[2.] Lecturer of Critical Care and Emergency Nursing, Faculty of Nursing, Damanhour University, Egypt.

Abstract:
Background: Excessive noise is a serious issue for patients in intensive care units, and it has the potential to have a negative psychological impact on patients' prognoses. As a result, the World Health Organization advises that hospitals' noise levels should not rise above 35 dB during the day and 30 dB at night. **Objective:** Evaluate the effect of implementing noise reduction nursing interventions on alarm fatigue and sound levels in intensive care. **Settings:** The study was conducted at the Damanhur Medical National Institute's general ICUs. **Subjects:** For this study, a practical sample of 30 critical care nurses was used. **Tools of the study:** Two tools were employed to gather the information. **Tool I:** was the nurses' alarm fatigue questionnaire, which was used to measure nurses' alarm fatigue. **Tool II:** was an assessment of nurse commitment to noise reduction interventions, which was used to assess nurses' commitment to noise reduction interventions. **Results:** The findings of the current study revealed that there was a statistically significant reduction in noise level before and after training the study group **(P= 0.001)**. **Conclusion:** Applying noise reduction interventions had a stronger effect on lowering the noise level score and alarm level of weariness. **Recommendations**: The current study advises minimizing patient exposure to noise and implementing preventative and reduction methods to battle noise in ICUs.

Keywords: Alarm fatigue, ICU, Noise reduction interventions & Sound level.

Introduction:
The health facility in the intensive care unit (ICU) is a vital facility designed to offer critically ill patients specialized care and near-real-time tracking of critical signs. Every step of ICU work is centered on the patient's care; however, the required activities and clinical gadgets generate noise **(Jung, et al, 2020).**

The United States Environmental Protection Agency, in reality, defines noise as "any sound that can produce an undesired physiological or mental impact in a man or woman". **(Pal, et al., 2022).** Regular staff members and equipment alarms are the main sources of noise in intensive care units, which patients frequently complain about as annoying and uncomfortable. According to research, alarm systems intended to catch the attention of caregivers by interfering with their advanced activities frequently produce excessive noise **(Darbyshire et al, 2019)**.

Excess noise is an unusual hassle in extensive care devices and may have poor results in regards to the patients' sleep quality **(Darbyshire et al, 2016 & Simons et al., 2018)**. In critically ill patients, sleep disturbances may also contribute to the development of delirium. It may also result in longer hospital stays in the ICU and persistent cognitive impairment even after discharge. Accordingly, high noise levels can affect sleep and cause "extensive care unit psychosis". Because of this, the World Health Organization has recommended that the maximum noise levels in hospitals no longer exceed 45 dB during the day and 30 dB and 35 dB during the night **(Van de Pol et al., 2017).**

Alarms from monitors, clinical gadgets, and a team of workers expansion in ICU. In addition, many clinical and nursing teams of workers in extensive care devices work collaboratively with a huge range of unbiased physicians, growing their publicity. In the ICU, many activities contain immoderate noise, and plenty of obligations require excessive awareness among healthcare workers. Importantly, a median sound strain stage of forty dB can disrupt activities that require awareness and increase the ability for error. **(Lewandowska, et al, 2020).**

According to scientific experts, surveillance alarms are one of the maximum disruptive elements inside the ICU due to the fact that they arise so frequently. In addition, ICU caregivers revel in excessive strain related to medical alarms and are afflicted by alarm fatigue. Moreover, they'll silence the alarm without acknowledging the patient **(Lewis & Oster, 2019).**

Between January 2009 and June 2012, ninety-eight detrimental activities had been recorded inside the United States because of a wrong or not-time response to an alarm, which included eighty that ended with the death of a patient. So, alarm fatigue endangers the safety of those who are afflicted by it. **(Purbaugh et al, 2014).**

Alarm fatigue happens when the repeated activation of alarms overwhelms a care issuer to the point that they're compelled to disregard or modify alarms in probably dangerous ways. Alarm fatigue is a trouble on account of desensitization and sensory overload because of the immoderate variety of alarms, which ends up in a lack of reaction amongst critical care nurses **(Sendelbach, & Funk, 2013).**

Alarms from tracking tools can be annoying for various reasons. It is difficult to locate the alarm and check for and confirm its supply. Alarms cause cognitive stress in medical staff members, notably due to a mismatch between the achievement of the interest, the distraction from it, and the prioritizing of the alarm's severity **(Ruskin & Hueske-Kraus., 2015)**.

Clinical alarm control is taken for consideration a huge technique for enhancing an affected person's effects and takes into consideration the Joint Commission Accreditation-compliant National Patient Safety Goal (NPSG). This group promoted stricter standards and procedures being implemented by hospitals. This group promoted stricter standards and procedures being implemented by hospitals related to relevant alarm indicator tracking and control. Thus, efforts to lessen the effect of noise with inside the ICU need to use a multi-faceted approach including editing staff conduct and practices, minimizing disruption because of gadgets and alarms, and optimizing the layout of the ICU. However, perhaps the most important aspect of this is to educate those involved in the care of critically ill patients about the effects of their behavior on patient comfort. **(Souza, et al, 2022)**

Additionally, strategies to lower the number of alarms have been reported by the Critical-Care American Association. These techniques include daily electrode changes, proper preparation of cardiac monitoring electrodes, and customizing oxygen saturation using pulse oximetry devices. Determine which alarm has sounded, cautiously turn on mechanical ventilation for the patient, and check that the syringe pump is properly positioned and fastened (**AACN, 2013**). Therefore, the purpose of this study was to investigate sound levels, learn about alarm frequencies, and figure out how sound levels relate to alarms. It was also determining the effect of implementing nursing interventions to reduce noise.

Aim of the study:

The aim of the study was to evaluate the effect of implementing noise reduction interventions on sound levels and alarm fatigue in intensive care units.

Research hypothesis:

Nurses who were subjected to the noise reduction interventions exhibited a lower rate of sound levels and alarm fatigue.

Materials and Method:

Research design:

A quasi-experimental research design was used to conduct this study.

Settings:

This study was conducted at the general ICUs at Damanhur Medical National Institute which are classified as general ICU I (15beds) and the general ICU II (13beds).

Subjects:

A convenience sample of 30 Critical Care Nurses was included in the study. Based on the power analysis using Epi- Info program applying the following parameters: population size: 90 admitted during 4 months, expected frequency: 50%, acceptable error 5 %, and confidence coefficient of 97 %.

Tools: To collect the necessary data for this study, two tools were used:

Tool I: Nurses' Alarm Fatigue Questionnaire: This tool was developed by the researcher after reviewing related literature **(Torabizadeh et al., 2017)**. This tool was used to measure nurses' alarm fatigue. It consisted of 13 questions on a 5- point Likert scale, with each item scored as always (0), usually (1), occasionally (2), rarely (3), or never (4). Questions 1 and 9 were scored reversely and ranged from always (4) to never (0). The overall score of the alarm fatigue questionnaire ranged from 8 (minimum) to 44 (maximum), with higher scores indicating a greater degree of the alarm fatigue. In addition, this tool involved nurses' demographic data, such as age, gender, education level, years of experience and previous in-service training.

Tool II: nurses' commitment to perform noise reduction interventions: This tool was developed by the researcher after reviewing related literature **(Vreman J et al., 2023)**. This tool was used to assess nurses' commitment to perform noise reduction interventions. It consisted of three parts.

Part I: This part was used to determine:

A. Number of alarms of different medical devices, which included the following:
   - Cardiac monitor alarms
   - Ventilator alarms
   - Pulse oximeter alarms
   - Infusion pump alarms
B. Nurse's response to alarm within 6 hours, which included no response, patient assessment and observation, responding to the patient's complaint, informing the doctor of the patient's condition, positioning the patient, and checking

and resolving contact and transmission problems.

C. Causes of alarms included contact and transmission problems, treatments and care interventions, inappropriate device settings, patient clinical condition, and patient movement in bed.
D. Category of alarms, which included false alarms, response required alarms, and attention and monitoring required alarms.

Part II: This part was used to identify noise levels during one month before and after implementing noise reduction interventions.

Part III: This part was used to assess the nurse`s commitment to performance of noise reduction interventions, which includes the following components:

- Communication related interventions
- Staff - related interventions
- Patient - related interventions
- Devices - related interventions
- ICU environment - related interventions
- Each item was scored by one if it met the intervention and zero if it did not.

Method:

- Approval from the ethical committee of the Faculty of Nursing at Damanhour University on December 16, 2021(No. 51-D) was obtained.
- An official letter was obtained from the Faculty of Nursing and sent to hospital administrative authorities to conduct the study after an explanation of the aim of the study.
- An official approval to carry out the study was obtained from the hospital administrative authorities to collect the necessary data from the selected settings.
- The study tools were developed by the researcher after reviewing the relevant literature **(Torabizadeh et al., 2017 & Vreman et al., 2020)**.
- The study tool was submitted to a jury of 7 experts in the field of critical care nursing to assess its content validity. The necessary modifications were done accordingly.
- A pilot study was carried out. It was conducted on 10 % of nurses (3 nurses) to assess the feasibility of the study and the applicability of the tools, and these nurses were not included in the study. The necessary modifications were made accordingly.
- The reliability of the study tools I and II was measured using Cronbach Alpha. The reliability and results were 0.78 and 0.85 respectively.
- The data collection started at the beginning of September 2022 and ended in February 2023.

Assessment phase of data collection:

The researcher visited the intensive care units at the previously mentioned settings by rotation 7 days during the morning shift to collect baseline data. An average of 3-5 nurses were observed and interviewed per day. At the beginning of the interview, the researcher explained the aim of the study and obtained their written approval to participate in the study prior to data collection. Then the researcher assessed the alarm fatigue by using the nurses' Alarm Fatigue Questionnaire (Tool I) and observed them to assess their interventions to decrease and prevent noise, and the researcher fulfilled the nurses' commitment to noise reduction interventions checklist (Tool II)

Pre-educational program implementation:

First, the questionnaires were distributed to all nurses individually so that they could assess alarm fatigue in the presence of the researcher to explain and answer the questions. On average, it took 10-15 minutes.

Second, the researcher monitored nurses' practice of noise reduction measures during shifts using an observational checklist. Each nurse was rated three times and averaged. In addition, the researcher observed the reaction of the nurse to various malfunctions of medical equipment, including their number, causes, and classification malfunctions. This observation period lasted four weeks.

- Along with those previously mentioned four weeks, the researcher also measured the noise level before starting the educational program daily at the morning shift. It was assessed before starting nurses' education.
- Causes, numbers, and categories of alarms for medical devices such as syringe pumps, pulse oximetry, and ventilators were recorded by a researcher.
- Sound levels were measured in decibels using an A-weighted scale dB (A) with a noise meter application downloaded on mobile and positioned in a central location of the unit, on a shelf of a supply column, at the height of the patient's head.

Compilation of the training program:

The training program was designed by the researcher based on nurses' needs for noise reduction measures; it was designed, reviewed, and adapted from related literature (American Association of Critical-Care Nurses 2013) to improve nurses' noise reduction knowledge and practice. The content was written in simple Arabic. It lasted eight weeks.

Implementation of the training program: The researcher was available six days a week in the intensive care unit of the aforementioned hospitals. Nurses were divided into six groups. There are 5

nurses in each group. The implementation phase was reached with one session every week for two days for each group. Every session consisted of a theoretical lecture on the first day, followed by a demonstration done by the researcher and a re-demonstration done by nurses for practice on the second day. Each session began with a summary of the previous session and new objectives, considering the use of simple Arabic language appropriate to the educational level of the nurses. There were 12 sessions in total (6 for information and 6 for practice). Theory classes started at 11:00-12:00 AM. The theoretical part of the program focused on knowledge. The researcher continued to confirm the information received, answered all questions, and gave suggestions. Practical training started on the second day at the same time, 11-12 AM.

- Group discussion was encouraged with continuous feedback to ensure understanding and achievement of the specific objective of the program.
- The training program lasted within 2 months, the researcher repeated sessions because of work overload circumstances.

Evaluation phase:

- Causes, numbers, and categories of alarms for medical devices such as syringe pumps, pulse oximetry, and ventilators were recorded by a researcher every hour for a duration of 6 hours daily until the evaluation phase had been finished.
- Nurses, commitment to the performance of noise reduction interventions, which included communication - related interventions, staff - related interventions, patient - related interventions, device - related interventions, and ICU environment - related interventions, was assessed by a researcher for each nurse every hour for a duration of 6 hours per day until every nurse in the study had been observed.
- The noise level was assessed and recorded by the researcher every hour for a duration of 6 hours daily until the evaluation phase had been finished.
- The evaluation phase was completed within 3 months. After finishing this phase, a questionnaire was given about the nurses' fatigue.
- The collected data was analyzed with an appropriate statistical test to find out if the noise level in the intensive care unit was reduced by measures to reduce noise level and alarm fatigue.

Ethical considerations:

- Informed written consent was obtained from the head nurses for observation.
- Data confidentiality was assured during the implementation of the study.

Results:

Table (1): Distribution of studied critical care nurses according to demographic data

Demographic data	No.	%
Gender		
Male	13	43.3
Female	17	56.7
Age (years)		
<30	13	43.3
30–<40	11	36.7
≥40	6	20.0
Mean ± SD.	32.23 ± 7.56	
Education		
Secondary school	7	23.3
Technical health institute	9	30.0
Bachelor's degree	14	46.7
Experience (years)		
<5	7	23.3
5-<10	12	40.0
≥10	11	36.7
Mean ± SD.	8.43 ± 5.82	
Training		
No	20	66.7
Yes	10	33.3

SD: ***Standard deviation***

Table (2): Comparison between the mean number, causes and categories of alarms before and after implementation of noise reduction interventions

Items	Before Interventions Mean ± SD.	After Interventions Mean ± SD.	t	p
Number of alarms of each medical device				
Cardiac monitor				
- Dysrhythmia	11.13 ± 3.44	9.50 ± 2.99	1.84	0.08
- Invasive bl.p	9.70 ± 2.60	8.93 ± 1.66	1.40	0.17
- Respirations	9.37 ± 2.67	9.31 ±3.04	0.37	0.72
Mechanical Ventilator Pulse	9.50 ± 2.62	9.40 ± 2.93	0.13*	0.005*
Oximeter	9.37 ± 1.99	8.80 ± 2.07	1.34	0.19
Infusion pump	7.60 ± 4.51	7.07 ± 3.89	1.13	0.27
Causes of alarms				
Contact and transmission problems	9.28 ± 3.90	8.42 ± 4.08	1.59*	0.001*
Treatments and care interventions	9.08 ± 3.32	8.72 ± 3.61	0.59	0.56
Inappropriate device setting	6.19 ± 2.41	5.47 ± 2.88	1.25*	0.002*
Patient clinical condition	3.86 ± 2.59	4.03 ± 3.10	0.38	0.71
Patient movement in bed	2.44 ± 3.36	2.50 ± 4.37	0.17	0.87
Categories of alarms				
False alarms	17.39 ± 2.61	16.47 ± 3.39	1.34	0.19
Response required alarms	11.08 ± 3.60	10.81 ± 2.74	0.40	0.69
Attention and monitoring required alarms	2.44 ± 1.71	1.78 ± 1.07	2.28*	0.03*
Nurse response				
No response	5.61 ± 3.29	5.58 ± 2.39	0.049*	0.002*
Patient assessment and observation	12.89 ± 3.40	12.53 ± 2.62	0.63	0.54
Responding to the patient complain	8.61 ± 2.69	8.28 ± 2.48	0.61	0.54
Informing the doctor of the patient's condition	3.75 ± 1.27	2.06 ± 1.33	1.26	0.22
Positioning the patient	1.17 ± 1.42	0.89 ± 1.01	1.02	0.31
Checking and resolving contact and transmission problems	0.64 ± 1.74	0.33 ± 0.63	1.01	0.32

t: Paired t-test *p: p value for comparing between* ***before*** *and* ***after*** *implementation of noise reduction interventions*

Table (3): Comparison between level of alarm fatigue and noise before and after the implementation of noise reduction interventions

No	Statement	Before Mean± SD.	After Mean± SD.	t	p
1.	I regularly readjust limits of alarms based on clinical symptoms of patients.	2.03± 1.33	2.33± 1.52	0.964	0.343
2.	I turn off alarms at the beginning of every shift.	2.20± 1.16	2.07± 1.11	0.472	0.641
3.	I hear a certain amount of noise in the unit	2.50± 1.33	2.43± 1.11	0.232	0.818
4.	I believe much of noise is from alarms of monitoring equipment.	2.83± 1.09	2.23± 1.25	2.983*	0.006*
5.	I pay more attention to alarms in certain shifts	2.33±1.35	2.93± 1.39	1.278	0.211
6.	In some shifts heavy workload prevents my quick response to alarms.	3.13±1.50	2.13±1.20	0.000	1.000
7.	When alarms go off repeatedly, I become indifferent to them.	2± 1.14	1.90±1.27	0.372	0.712
8.	Alarm sounds make me nervous.	2.97±1.16	2.37±0.89	1.755	0.090
9.	I react differently to low-volume and high-volume alarms of the ventilator.	2 ± 1.39	2.27 ±1.08	0.812	0.423
10.	I'm more responsive to alarm sounds, when I'm upset and nervous.	1.87±1.20	1.27±1.14	2.041*	0.049*

No	Statement	Before	After	t	p
		Mean± SD.	Mean± SD.		
11.	I lose my patience, when alarms go off repeatedly and continuously.	2± 1.31	1.60±1.16	1.484	0.149
12.	Alarm sounds prevent me from focusing on my professional duties.	2 ± 1.36	1.30±1.32	1.966	0.059
13.	I pay less attention to the alarms of the equipment at visiting hours.	2.10 ±1.54	1.73 ±1.48	0.983	0.334
Total score				2.231*	0.034*
Mean ± SD.		27.9± 5.74	25.63± .87		
% score					
Mean ± SD.		53.65± 11.03	49.29±11.29		
Level of noise Mean ± SD.		46.35± 9.14	37.99± 9.38	3.221*	0.003*

t: Paired t-test *p: p value for comparing between Before and After the implementation of noise reduction interventions*

: Statistically significant at p ≤ 0.05* *SD: **Standard deviation*

Table (4): Comparison of the studied nurses, commitment regarding the implementation of reducing noise interventions

Interventions of noise reduction	Before Interventions				After Interventions				McN_p
	Unmet		Met		Unmet		Met		
	No.	%	No.	%	No.	%	No.	%	
Communication -related intervention: Give instructions to:									
- Pause button on monitor during nursing care	5	16.7	25	83.3	2	6.7	28	93.3	0.45
- Place monitor on standby when the patient is off monitor.	6	20	24	80	1	3.3	29	96.7	0.06
- Answer all alarms by everyone.	10	33.3	20	66.7	3	10	27	90	0.04*
- Turn off phones during work	16	53.3	14	46.7	9	30	21	70	0.14
- Set monitor's alarm on medical devices to the appropriate level	24	80	6	20	17	56.7	13	43.3	0.07
- Make an orientation for new staff; she or he has to answer an alarm.	16	53.3	14	46.7	7	23.3	23	76.7	0.04*
Staff related interventions:									
- Put on soft shoes and don`t pull them Off	9	30	21	70	6	20	24	80	0.55
- Respond immediately if the alarm Rings	9	30	21	70	7	23.3	23	76.7	0.77
- Limit conversations between the ICU Staff	18	60	12	40	10	33.3	20	66.7	0.08
- Keep the tone of voice during conversation quite	22	73.3	8	26.7	18	60	12	40	0.34
- Keep phones silent	26	86.7	4	13.3	26	86.7	4	13.3	1
Devices related interventions									
- Change ECG electrodes daily	12	40.0	18	60	7	23.3	23	76.7	0.30
- Prepare of the skin	14	46.7	16	53.3	6	20	24	80	0.04*
- Demonstrate ideal lead placement	10	33.3	20	66.7	6	20	24	80	0.34
- Change pulse oximetry sensors as needed.	11	36.7	19	63.3	6	20	24	80	0.18
- Check skin integrity under pulse oximetry sensor	19	63.3	11	36.7	9	30	21	70	0.002*
- Maintain mechanical ventilator alarm correctly	24	80	6	20	10	33.3	20	66.7	<0.001*
- Examine patient’s vital signs to assess Alarms	26	86.7	4	13.3	10	33.3	20	66.7	<0.001*
- Change alarm parameters to reflect changes in patient condition.	27	90	3	10	16	53.3	14	46.7	0.003*
- Press vital sign intended for change.	29	96.7	1	3.3	25	83.3	5	16.7	0.13
- Adjust default alarms	30	100	0	0	25	83.3	5	16.7	0.06

Interventions of noise reduction	Before Interventions				After Interventions				McN_p
	Unmet		Met		Unmet		Met		
	No.	%	No.	%	No.	%	No.	%	
Environment related interventions									
- Check rubber strip on the door	18	60	12	40	8	26.7	22	73.3	0.02*
- Open and close drawers cautiously	19	63.3	11	36.7	11	36.7	19	63.3	0.08
- Check silent garbage cans are used.	20	66.7	10	33.3	14	46.7	16	53.3	0.21
- Adjust the volume of hospital announcements	23	76.7	7	23.3	14	46.7	16	53.3	0.04*
- Dim the lights in the evening	26	86.7	4	13.3	15	50	15	50	0.01*
- Restock supplies during evening rather than night	30	100	0	0	23	76.7	7	23.3	0.02*
Total score Mean ± SD	12.87 ± 7.24				22.60 ± 6.67				<0.001*

McN: McNemar test. *p: p value for comparing between* ***Before*** *and* ***After***
**: Statistically significant at p ≤ 0.05*

Table (1): Illustrates the distribution of the critical care nurses according to their demographic data. Regarding gender, this table shows that more than half of the study sample was female (56.7%). Regarding age, it can be noted that the mean age of critical care nurses was 32.23± 7.56 years. Moreover, nearly half of them was <30 years old. As regard the education level and years of experience, nearly half of the study sample (46.7%) and 40 % had a bachelor's degree of education and between 5- <10 years of experience. Concerning previous training, it can be noted that more than two thirds of the study sample (66.7 %) did not present any training programs related to noise reduction.

Table (2): Shows a comparison between the mean number of alarms for each medical device, causes and categories of alarms before and after the implementation of noise reduction interventions. Regarding the mean number of alarms, it can be noted that the mean number of alarms caused by all medical devices decreased after the implementation of noise reduction interventions. Moreover, the number of alarms caused by mechanical ventilators decreased from 9.50 ± 2.62 before implementation of noise reduction interventions to 9.40 ± 2.93 after implementation of noise reduction interventions. The difference between them was statistically significant (p= <0.005).

Concerning, the means of causes of alarms; it can be observed from this table that contact and transmission problems decreased from 9.28 ± 3.90 before interventions to 8.42 ± 4.08 after the implementation of interventions, with a significant difference (p=001). In addition, alarms caused by inappropriate device settings decreased from 6.19 ± 2.41 before the implementation of noise reduction interventions to 5.47 ± 2.88 after the implementation of noise reduction interventions. The difference was statistically significant (p= 002).

As regard the means of categories of alarms, it can be noted from this table that all means decreased after interventions. Moreover, the mean attention and monitoring required alarm category decreased from 2.44 ± 1.71 before the implementation of noise reduction interventions to 1.78 ± 1.07 after the implementation of noise reduction interventions. The difference was statistically significant (p= 0.03).

Regarding nurses' responses to alarms, it can be observed from this table that the mean of no response decreased from 5.61± 3.29 before implementation of noise reduction interventions compared to 5.58 ± 2.39 after implementation of noise reduction interventions. The difference was statistically significant (p= 002).

Table (3): Shows a comparison between the level of alarm fatigue and noise before and after the implementation of noise reduction interventions. In relation to the total score of the fatigue alarm, it can be noted that the mean level of the alarm fatigue score before the implementation of noise reduction interventions was 53.65 ± 11.03 as compared to 49.29 ± 11.29 after the implementation of noise reduction interventions. The difference was statistically significant (P= 0.034). It can be observed from this table that the mean noise level score before the implementation of noise reduction interventions was 46.35 ± 9.14 as compared to 37.99 ± 9.38 after the implementation of noise reduction interventions. The difference was statistically significant (P= 0.003).

Table (4): Demonstrates a comparison of the studied nurses' commitments regarding the implementation of reducing noise interventions, which include six components: communication, staff, patients, devices, and ICU environment - related interventions.

Concerning, interventions related to staff, it can be observed from this table that 46.7 % of the study

sample was met for orientation of new staff if she or he answered an alarm before the implementation of noise reduction interventions, compared to 76.7 % was met after the implementation of noise reduction interventions. The difference was statistically significant (p= <0.035).

Relating to interventions related patients; 16.7 % of the study sample were met for wearing personal protective equipment before implementation of noise reduction interventions compared to 36.7 % were met after implementation of noise reduction interventions. The difference was not statistically significant (p= <0.070).

Regarding interventions related to devices, it can be noted from this table that 53.3 % of the study sample was prepared of the skin before the implementation of noise reduction interventions, compared to 80 % that was prepared after the implementation of noise reduction interventions. The difference was statistically significant (p=<0.04). It can also be observed from this table that 36.7 % of the study sample was used to check skin integrity under a pulse oximetry sensor before the implementation of noise reduction interventions, compared to 70 % after the implementation of noise reduction interventions. The difference was statistically significant (p= 0.002). Also, 53.3 % of the study sample was maintaining mechanical ventilator alarms correctly before the implementation of noise reduction interventions, compared to 66.7 % after the implementation of noise reduction interventions. The difference was statistically significant (p= <0.001).

Relating to changing alarm parameters to reflect changes in patient condition, it can be noted from this table that 10 % of the study sample were met before the implementation of noise reduction interventions, compared to 46.7 % were met after implementation of noise reduction interventions. The difference was statistically significant (p= 0.003).

In relation to interventions in the ICU environment, it can be noted from this table that 73.3 % of the study sample checked the rubber strip on the door before the implementation of noise reduction interventions, compared to 40 % after the implementation of noise reduction interventions. The difference was statistically significant (p= <0.021), and 13% of the study sample met the requirement of dimming the lights in the evening before the implementation of noise reduction interventions, compared to 50 % after the implementation of noise reduction interventions. The difference was statistically significant (p= 0.007)

Nurses` evaluation of the commitment of alarm intervention revealed that the mean nurse commitment score was 12.87 ± 7.24 before the implementation of noise reduction interventions compared to 22.60 ± 6.67 after the implementation of noise reduction interventions, which means that there was a positive association between nurse commitments of alarm intervention and nurse education. The difference was statistically significant (P= <0.001).

Discussion:

Noise and alarm fatigue are significant problems that lead to many emotional events **(Chai X et al. 2023).** The aim of this study was to evaluate the effect of noise reduction measures on sound levels and alarm fatigue in intensive care units. Regarding noise level, the current study result revealed that the mean noise level score after implementation of noise reduction interventions was less than before implementation of noise reduction interventions **(Table III)**. This can be attributed to the fact that applications of noise reduction interventions have played their respective significant roles in reducing noise levels according to the recommended WHO guidelines. Moreover, applications of noise reduction interventions have played a vital role in decreasing the number of alarms and increasing the level of knowledge and awareness about the causes of alarms and responses related to medical devices all of these intervention were based on guidelines for managing alarms which, have been issued by the American Association of Critical Care Nurses (AACN) and suggested that orientation and ongoing education as solutions **(AACN, 2013)**.

According to AACN guidelines the awareness of causes and responses to medical devices decrease noise level. In this study, nurses' responses (no response) and the number of alarms caused by all medical devices decreased after the implementation of noise reduction interventions, specifically mechanical ventilator alarms **(Table II)**. Nurses responded adequately, after their education, intentionally to a mechanical ventilator because it is a serious machine that keeps patients' breathing and saves lives. Tegnestedt determined that 64% of disruptive sounds and noise were caused by monitor alarms **(Tegnestedt et al., 2013)**. In previous studies conducted at intensive care units identified alarm signals as the main sources of disturbing noise **(Darbyshire et al., 2016)** and alarm devices produce very little sound except when alarms are activated (>50 dB) (**Darbyshire et al., 2019**). Moreover, in many studies it were recommended that noise reduction is a part of an intervention package that lowers average sound pressure levels **(Nannapaneni et al., 2015; Patel et al., 2014)**.

Alarm fatigue and overload significantly reduce the well-being of ICU nurses. In this study, it was found that the majority of nurses had alarm fatigue before the implementation of noise reduction interventions. This may be because in Egypt, there are no hospitals

training nurses to deal with constant alarms and no studies showing how alarm fatigue can affect patient safety. Similarly, many studies have agreed that nurses complain of alarm fatigue, and this has unpleasant consequences for patient safety (**Seok et al. 2023**; **Casey et al., 2018**). In addition, the alarm fatigue level scores decreased by 11.29 after the implementation of noise reduction measures **(Table III)**. This is because nurses discovered the presence of alarm fatigue in a post- educational training program and became aware of its impact on nurses and also unpleasant consequences patient safety. Moreover, these results were supported by a study done by (**Elhessewi et al., 2017**) who conducted a study on determining critical care nurses' alarm fatigue: developing alarm management guideline. It was concluded that an alarm fatigue score of critical care nurses decreased after nursing management guideline and there was a significant statistical difference between two group regarding alarm fatigue.

On the other side, there are controversial results reported by (**Seifert et al., 2021**) who stated that greater fatigue among the respondent nurses was described by the researcher, who examined the levels before and after alarm management training. Alarm fatigue results increased from the pre-implementation level to the post-implementation, which indicates that there was no significant statistical difference between those periods.

Concerning the commitment of nurses to noise reduction, the results of this study showed that there was a significant improvement after the implementation of the noise reduction measures than before the implementation of the noise reduction measures, meaning that there was a positive relationship between nurses' commitment to disorder intervention and nurse education **(Table IV)**. Moreover, inappropriate device setting as a cause of alarm and attention and monitoring required alarms as a category of alarms improved significantly after the educational program in this study **(table II).** This may be because the best strategy for reducing staff noise is to educate all of them and wait for their behavior to change.

Moreover, nurses are in charge of handling monitor alarms. Proper electrode placement, skin preparation, and alarm settings customized to each patient's needs are a few practical ways to reduce false alerts **(Edworthy, 2013)**. Other important recommendations of the AACN concern proper skin preparation for daily electrode replacement (ECG), replacement of pulse oximeter sensors when necessary, monitoring of patients only with clinical recommendations, and the establishment of a team corresponding to the alarm system. (**Lewis & Oster 2019**). The same organization released a revised protocol in 2018 to address issues with alert handling based on research and readiness techniques. Turmell conducted a study to assess the efficacy of tactics used at an American hospital based on these suggestions. It was demonstrated that there were 30% fewer clinical problems (**Turmell et al. 2017**).

The current study's findings concur with those of (**Konkani & Oakley., 2012**), who claimed that staff education is one of the most effective approaches for lowering noise in intensive care units. Additionally, these results were consistent with a study by **(Kol et al., 2015**) that found that staff education reduced the noise level from 65 dB-A to 63.1 dB-A. But in a contrary with our findings, a study that showed behavior modification training is successful in lowering noise levels in hospitals while, education is not enough (**Konkani & Oakley. 2014**). That is because unfortunately, there is a significant impact on the proper setting of alarms or the management of alarms in general due to factors like the large number of tasks, the adequate number of nurses, fear related to prior bad experiences, knowledge, and skills, or the lack of common technologies **(Ruppel, et al., 2019).** So, there is a great deal to train nurses in different circumstances. The introduction of specific nursing practices and nurse training should be key components of crisis management. Training is necessary for such a dynamically growing technology.

Conclusion:

Based upon the findings of the current study, the present study revealed that implementation of noise reduction interventions had a better effect on reducing noise level score and alarm level of fatigue, and there was a positive association between nurse commitment to alarm intervention after nurse education.

Recommendations:

According to the study's findings, the following recommendations can be considered:

1. ICUs should routinely quantify the amount of noise present, and patients should be assessed for noise sensitivity.
2. Guidelines for prevention and reduction should be created, and patient exposure to noise should be kept to combat noise in ICUs.
3. Awareness training should be given to all ICU staff members to lessen noise.
4. Including nurses in the orientation phase while beginning to use new machines and modify their alarm settings to raise nurses' knowledge of the existence of alarm fatigue.

Limitation of the study:
The ICU `s nurses work overload affected research conduct and their commitment to the performance of noise reduction intervention, so it diminished the efficiency of reducing noise interventions. Moreover, this study needed to be replicated on a large sample size for generalization of results.

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