

EMPIRICAL RESEARCH MIXED METHODS OPEN ACCESS

Nurses' Alarm Fatigue Levels in Adult Intensive Care Units and Their Strategies to Reduce Fatigue: A Parallel Design

Ayşe Uçak¹  | Fatma Cebeci²  | Arzu Tat Çatal² 

¹Faculty of Health Sciences, Nursing Department, Burdur Mehmet Akif Ersoy University, Center/Burdur, Turkey | ²Faculty of Nursing, Surgical Nursing Department, Akdeniz University, Campus/Antalya, Turkey

Correspondence: Arzu Tat Çatal (arzutatben@gmail.com)

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ABSTRACT

Background: Alarm fatigue is a challenge for nurses and patients. Also, feasible strategies to reduce/manage alarm fatigue are still unclear.

Aim: This study aimed to identify adult intensive care nurses' alarm fatigue levels and strategies to reduce alarm fatigue.

Design: A convergent parallel design was employed.

Method: The study was conducted between January and June 2022 in adult intensive care units of a university hospital, with 67 nurses in the quantitative phase and 14 in the qualitative phase. Quantitative data were collected using a personal information form, the Satisfaction Visual Analog Scale and the Nurses' Alarm Fatigue Questionnaire. Qualitative data were collected using a semi-structured interview form. Descriptive analyses, Mann–Whitney *U*, Kruskal–Wallis and Multiple Linear Regression analysis were used to evaluate quantitative data. The inductive content analysis method was utilised to evaluate qualitative data. The STROBE and COREQ checklists were employed to report the study.

Results: In the quantitative phase, increased intensive care unit working hours, available alarm management support for managing alarms, and increased satisfaction level were negatively associated with alarm fatigue. Three main themes (“building an alarm management culture”, “safe care environment” and “improving the features of alarm equipment/devices”) and 10 sub-themes were elicited from interview data about the reduction of alarm fatigue.

Conclusions: In the study, adult intensive care nurses' alarm fatigue levels and strategies to reduce fatigue were revealed. These strategies should be applied to reduce alarm fatigue in intensive care units.

Implications for Practice: Healthcare providers should develop and implement proactive strategies through effective organisational management to prevent and reduce alarm fatigue so that an alarm management culture can be built, employee satisfaction can be increased, a safe care environment can be provided, and the features of alarm devices can be improved.

Reporting Method: The study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) and Consolidated Criteria for Reporting Qualitative Research (COREQ) checklists.

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Summary

- What problem did the study address?
 - This article presents the alarm fatigue levels of nurses working in adult intensive care units and strategies to reduce alarm fatigue.
- What were the main findings?
 - In this article, the score of nurses for alarm fatigue levels was 14.03 ± 7.01 .
 - Nurses' strategies to prevent alarm fatigue were grouped under three main themes: creating an alarm management culture, a safe care environment and developing the features of alarming equipment/devices.
- Where and on whom will the research have an impact?
 - In this article, the experiences of adult intensive care nurses reveal the importance of creating and actively using protocols that will develop an alarm management culture, provide a safe care environment and develop the features of alarming devices by multidisciplinary team members in preventing alarm fatigue.
- What does this paper contribute to the wider global clinical community?
 - This article shows that nurses' alarm fatigue levels are negatively affected by working in intensive care for 1 to ≤ 5 years, mixed shift work, working more than 40h a week, a lack of alarm management support and low satisfaction.
 - Three main themes and ten sub-themes were obtained from in-depth individual interviews with nurses in the study as strategies to reduce alarm fatigue.
 - It is essential to use strategies that emerge from the experiences of adult intensive care nurses in determining, preventing and managing the dimensions of alarm fatigue.

1 | Introduction

Monitoring critically ill patients is a complex process, and numerous medical device alarms are used in intensive care units to monitor patients. Intensive care nurses are key professionals who are a fundamental component of the treatment process and manage many monitoring devices (Joint Commission International-JCI 2023). In the intensive care unit, parameters, such as vital signs (e.g., heart rate), arterial blood pressure, oxygen saturation, and fluid and medication infusion, are automatically monitored with many different devices (Chromik et al. 2022). As a result of the increasing use of equipment in hospitals as a product of modern technology, noise generated by the combination of these devices during care is a major factor contributing to alarm fatigue (JCI 2023; Nyarko et al. 2023). Nurses are overwhelmed due to alarms (especially non-actionable alarms) and having to respond to them (Movahedi et al. 2023a; Nyarko et al. 2023). The number of false alarms is higher than that of true ones (Nyarko et al. 2023), and approximately 820 alarm signals are generated per patient a day by devices in adult intensive care units. Also, this figure can reach up to 1503 (Lobo et al. 2024). Alarms are a critical element of care. However, failure to resolve alarms poses a threat to patient safety by leading to inattention, normalisation and delayed

responses to them (Movahedi et al. 2023b). Alarm fatigue occurs when a large number of clinical alarms are technically incorrect or clinically irrelevant (Nyarko et al. 2023; Sowan 2024). Alarm fatigue/desensitisation usually occurs due to ignoring alarms and not responding or responding slowly to actionable ones because the majority of them are irrelevant or non-actionable (Albanowski et al. 2023). The resulting fatigue/desensitisation can cause valid alarms that require intervention to be missed, ignored, or even disabled (Chromik et al. 2022; JCI 2023). As intensive care team members become desensitised ("fatigued") to alarms, this situation creates a serious patient safety issue due to missed care (Chromik et al. 2022; JCI 2023; Sowan 2024). In addition, it can seriously harm healthcare professionals (Sowan 2024).

2 | Background

Alarm management is among the 2023 patient safety goals of the Joint Commission International. JCI aims to reduce alarm-related harm to patients (JCI 2023). Clinical alarms are at the top of the "Top Ten Healthcare Technology Hazards List" in the 2014 report of the Emergency Care Research Institute (ECRI). Nurses must manage alarms more carefully than ever, especially in critical areas (ECRI 2020). According to intensive care nurses, unnecessary alarms increase their workload, affect patient care negatively and reduce trust in alarm systems (Lewandowska et al. 2020). Despite national guidelines and increasing research on alarm system safety, alarm fatigue continues to be a critical burden on health. Alarm fatigue is a complex phenomenon that must be evaluated in the context of clinical settings. Given this complexity, there is little information on how to eliminate alarm fatigue and improve alarm system safety (Sowan 2024). Workload, complexity of advanced medical devices, a lack of a team approach to alarms and lack of training on alarm systems have been stated as the main causes of alarm fatigue (Lewandowska et al. 2020; Sowan 2024). Previous studies on alarm fatigue in intensive care nurses have mostly been conducted quantitatively or qualitatively. They have been carried out in the United States (Claudio, Deb, and Diegel 2021), Europe (Wunderlich et al. 2023) and Asia (Ding et al. 2021) (Movahedi et al. 2023a, 2023b; Nyarko et al. 2023), and there is limited research in Türkiye (Erbay Dallı and Bağcı Demirpınar 2024; Akturan et al. 2022). It has also been reported that there is a need for different and high-quality studies on the management of alarm fatigue in nurses (Nyarko et al. 2023). The investigation of strategies for alarm fatigue and its reduction in intensive care nurses is critical in ensuring and maintaining patient safety by increasing the awareness of healthcare institutions, managers and healthcare professionals about alarm management. In addition, there is a need for research that provides an integrated approach to the problem by utilising both objective and subjective data to reveal intensive care nurses' alarm fatigue levels and strategies to reduce them (Long, Silva, and Boswell 2020; Polit and Beck 2021).

3 | The Study

3.1 | Aim

This mixed-method study sought answers to the following questions:

- What is the level of alarm fatigue among nurses in adult intensive care units?
- What are the variables/related factors affecting alarm fatigue among nurses in adult intensive care units?
- What are nurses' strategies to reduce alarm fatigue in adult intensive care units?

4 | Methods

4.1 | Design

This study was conducted using the convergent parallel method design, which is a mixed-methods approach. A mixed method was used because it allows for a better understanding and in-depth examination of the research problem (Long, Silva, and Boswell 2020; Creswell and Clark 2018). Qualitative and quantitative data were collected with equal priority and simultaneously. The results were combined during interpretation (Creswell and Clark 2018; Long, Silva, and Boswell 2020; Polit and Beck 2021). The quantitative phase was descriptive and correlational, and the qualitative phase was phenomenological. Participants were recruited using purposive criterion sampling (Polit and Beck 2021). The study was registered at Clinical Trials. The STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) (Appendix S1) and COREQ (Consolidated Criteria for Reporting Qualitative Research) (Appendix S2) checklists were employed to report the study.

4.2 | Setting and Sample

The study was conducted with nurses working in secondary (one medical intensive care unit) and tertiary level (three anaesthesia intensive care units, three medical intensive care units and one cardiovascular intensive care unit) adult intensive care units of a university hospital with a capacity of approximately 1000 beds, 87 of which were in intensive care units. The average nurse/patient ratio in the adult intensive care units was 1:4. Available conditions were not appropriate for achieving a standard nurse/patient ratio in intensive care units. Nurses were not given standard training on alarms other than orientation processes and information provided when a new alarm device arrived. Approximately half of the nurses participating in the study described this information as alarm management support. In the hospital where the study was conducted, ward nurses worked between 8.00 and 16.00, while other nurses worked 8 or 16 h of mixed shifts at different times and days.

4.2.1 | Quantitative Phase

In the quantitative phase of the study, the minimum sample size was calculated as 67 subjects, based on a study in which the standard deviation of the "Nurses' Alarm Fatigue Questionnaire" was $\sigma = 6.82$, the population size was 106, and the confidence interval was 95% (Kahraman 2020) ($t = 1.96$; $d = 1$). Nurses who had been working in the secondary and tertiary-level adult intensive care units for at least 1 year were included in the study. The quantitative phase was conducted with 67 nurses.

4.2.2 | Qualitative Phase

The data collection process in the qualitative phase was terminated with 14 nurses when the emerging concepts and processes began to repeat (Polit and Beck 2021). The exclusion criterion was determined as the desire to leave the research at any time.

4.3 | Data Collection and Instruments

Data were collected between 6 January and 30 June 2022 after the ethics committee and institutional permissions were obtained. A password-protected and secure Google document link (<https://forms.gle/Vd9n79FAYKo9RjQY7>) was sent to intensive care nurses who wanted to participate in the study via their institutional e-mails to collect quantitative data. Participants were assured that participation was completely voluntary and that they could withdraw at any time. An initial assessment was performed to verify the eligibility and availability of interested participants, and then interview times were scheduled. A personal information form, the Satisfaction Visual Analog Scale and the Nurses' Alarm Fatigue Questionnaire were used to collect quantitative data in the study. The personal information form included questions about the participants' descriptive characteristics (age, gender, marital status, education, the level of the intensive care unit, total work experience in the intensive care unit, shift type, total working hours a week and presence of alarm management support in the intensive care unit they worked in). The satisfaction of the nurses with the unit they worked in was assessed with the Satisfaction Visual Analog Scale. The values on the scale range from 0 (not satisfied at all) to 100 (very satisfied). The Turkish form of the Nurses' Alarm Fatigue Questionnaire was used in the study. The score obtained from this nine-item and four-point Likert-type scale varies between 0 and 36. High scores indicate alarm fatigue. The scale does not have a cut-off point. High scores indicate that the nurse's performance is negatively affected (Kahraman and Başkale 2023; Torabizadeh et al. 2017). In the Turkish validity and reliability study, Cronbach's alpha value of the scale was found to be 0.80. In our study, the alpha reliability coefficient of the scale was calculated as 0.83.

Individual in-depth interviews were conducted with the participants who agreed to participate in the qualitative phase by using a semi-structured interview form. This form consisted of the following open-ended questions that would help clarify the study phenomenon in accordance with the qualitative nature of the research.

- What do you think about the alarms you are exposed to in the intensive care unit?
- What are your strategies to reduce alarm fatigue in the intensive care unit?
- Is there anything else you would like to add or say about the topic?

In addition, some probing questions based on nurses' answers were asked to increase the depth of the interview (What do you mean? Can you explain it more? What do you mean by...? and How did it affect...?) The interview questions were designed based on theoretical sampling, considering maximum diversity

in terms of gender, level of education, type of intensive care unit and work experience. The saturation point criterion was used to determine the number of interviewees, and the interviews were terminated when no new elements were identified. The interviews were conducted in a suitable room that was determined by the intensive care nurses and was a psychologically and spatially comfortable environment where the participants could feel good. Individual interviews lasted 26 min on average.

4.4 | Data Analysis

Within the scope of our research questions, quantitative and qualitative data were collected simultaneously in accordance with the convergent parallel design. In the discussion section, the integration of quantitative and qualitative evidence was interpreted through analytical generalisation by combining the data without transformation.

4.4.1 | Quantitative Components

Statistical Package for the Social Sciences Statistics 23.0 (IBM Corp., Armonk, NY) was used to perform all data analysis. The normality of the data was tested with the Shapiro–Wilk test. Descriptive statistics were summarised as frequency (n), percentage (%), mean, standard deviation (SD), median, range (min–max) and interquartile range (25–75 percentile). Mann–Whitney U test and Kruskal–Wallis test were used for non-parametric comparisons of scale scores between the independent groups. Post hoc analysis was performed using Bonferroni correction. Multiple linear regression analysis was performed to find the independent factors associated with alarm fatigue. Cronbach's alpha coefficients were calculated for the reliability analysis. A two-sided p value < 0.05 was considered statistically significant. The support of a statistician was received for the research.

4.4.2 | Qualitative Components

The inductive content analysis method was employed in the analysis of qualitative data of the study. All recorded interviews were transcribed and transferred to a Microsoft Word file without editing any of the aspects and details. The analysis was done manually; no software was utilised. Throughout the process, researchers independently reviewed and coded individual transcripts, regularly referring to the original data. The entire process of data collection, coding, analysis and development of main categories was documented for controlling purposes when necessary. All researchers carefully reviewed the transcripts and data and participated in the entire analysis process to increase internal validity. All findings were elicited without adding any comments. All categories and themes were presented with key interview quotes and labelled using an alphanumeric code (P1, P2 [participant number], 16 years [length of intensive care experience]).

4.5 | Rigour and Quality Criteria

The interviews were conducted by the same researcher to support inter-rater reliability. The content analysis, defined by Graneheim

and Lundman (2004), was used in the analysis of the data. The raw data were read several times by all researchers to understand the general content. The transcripts were examined and read extensively. The text content was divided into meaningful units consisting of several words, sentences or paragraphs containing interrelated factors. Meaningful units were coded and condensed while preserving their basic content. The codes were interpreted and compared in terms of similarities and differences, and sub-themes were obtained. Moving forward and backward between all text pieces was considered during the analysis process. Sub-themes were combined to determine the themes. To increase the validity of the themes and sub-themes, three authors coded the participants' statements separately. The researchers came together to reach a consensus to select the most appropriate meaning unit from the data and to evaluate the scope of the categories. In addition, to increase the external reliability of the study, all data collection tools, raw data and coded data, along with the researchers' perceptions, notes and conclusions that formed the basis of the report, were submitted to an external expert for verification. The external expert confirmed all the findings. The results were not shared with the participants. The interviews were conducted in Turkish, and the quotations were translated into English by a bilingual translator and checked.

4.6 | Ethical and Research Approvals

The research was conducted in accordance with the principles of the Declaration of Helsinki. Before the research was initiated, the approval of the Clinical Research Ethics Committee of the relevant institution, the permission of the institution where the research was conducted, and the informed consent of the participants were obtained. Audio recordings, data transcriptions and analyses were performed under pseudonyms.

5 | Results

5.1 | Demographic and Quantitative Results

The mean score of the nurses on the alarm fatigue questionnaire was 14.03 ± 7.01 (min–max: 0–36). The mean age of the 67 nurses participating in the study was 29.54 ± 5.51 (min–max: 21–48) years. Of the participants, 82.1% were female, 89.6% had an undergraduate degree, 88.1% worked shifts and 67.2% worked in a tertiary-level intensive care unit. The mean satisfaction with the unit that the nurses worked in was 64.1 ± 24.06 (min–max: 0–100). More than half of the participants (52.2%) reported that they could not receive alarm management support when they needed it, especially during night shifts.

The alarm fatigue score of nurses who worked in the intensive care unit for 1 to ≤ 5 years was significantly higher than the score of those who worked for ≥ 11 years ($p = 0.034$ and $p = 0.002$, respectively). Participants working more than 40 h a week had higher alarm fatigue scores than those working ≤ 40 h ($p = 0.019$). Additionally, it was found that alarm fatigue was higher in nurses working shifts than in those working day shifts permanently ($p = 0.020$) and in those who could not receive alarm management support when they needed it than in those who could ($p < 0.001$). The result was statistically significant (Table 1).

TABLE 1 | Alarm Fatigue Scale scores according to participants' descriptive characteristics ($n = 67$).

Variables	<i>n</i> (%)	Median (IQR) ^a	Test value	<i>p</i> ^c
Gender				
Female	55 (82.1)	14 (10–19)	$Z = 0.098$	0.922
Male	12 (17.9)	13.5 (10.5–19)		
Educational status				
Health vocational high school/associate degree	7 (10.4)	10 (5–20)	$Z = 0.750$	0.453
Undergraduate/Postgraduate	60 (89.6)	14 (11–19)		
The level of the intensive care unit				
Level II	22 (32.8)	15 (11–22)	$Z = -1.338$	0.181
Level III	45 (67.2)	14 (10–16)		
Total work experience in the intensive care unit				
1 ≤ 5 years	47 (70.1)	15 (12–20)	$KW = 12.097$	0.002^b
6–10 years	11 (16.4)	14 (6–16)		
≥ 11 years	9 (13.5)	7 (6–7)		
Total weekly working hours				
≤ 40 h	25 (37.3)	13 (7–15)	$Z = 2.345$	0.019
> 40 h	42 (62.7)	15 (12–20)		
Shift type				
Working day shifts continually	8 (11.9)	6.5 (5–11.5)	$Z = 2.335$	0.020
Mixed shift work	59 (88.1)	14 (11–19)		
Alarm management support				
No	35 (52.2)	16 (14–20)	$Z = -3.880$	< 0.001
Yes	32 (47.8)	11.5 (6.5–14)		

Abbreviations: KW, Kruskal–Wallis test; Z, Mann–Whitney *U* test.

^aSince the nurses' Alarm Fatigue Scale scores did not meet the normal distribution assumption, Median (50% percentile) and IQR (25–75 percentile) values were used.

^bSignificant difference = 1–3.

^cStatistically significant *p* values are shown in bold.

The mean item and total Alarm Fatigue Scale scores of the participants are given in Table 2. The highest-scored item was “I usually hear a certain amount of noise in the environment/clinic”, and the lowest-scored item was “I pay less attention to equipment alarms during visiting hours”.

The factors independently affecting nurses' Alarm Fatigue Questionnaire scores were evaluated with multiple linear regression analysis (Table 3). The findings indicated that increased ICU working time ($\beta = -0.368, p = 0.007$), availability of alarm management support to manage alarms ($\beta = -0.307, p = 0.004$) and increased satisfaction level ($\beta = -0.211, p = 0.049$) were negatively associated with alarm fatigue.

5.2 | Qualitative Results

The characteristics of the adult intensive care nurses who participated in the qualitative phase of the study are given in Table S1. As a result of the content analysis of the qualitative interviews in the study, nurses' opinions and suggestions to reduce alarm

fatigue in adult intensive care units were grouped under three main themes: “building an alarm management culture”, “safe care environment” and “improving the features of alarm equipment/devices” (Table 4).

5.2.1 | Building an Alarm Management Culture

5.2.1.1 | Personalised Alarm Settings. Regarding alarm management, all participants stated that when patient-centred care was focused and device alarm limits were set specifically for the patient and their condition, unnecessary alarms and alarm fatigue could be prevented. One participant expressed this situation as follows: “Focusing on patient-centered care can be a solution to reduce alarm fatigue. To do this, it is necessary to know what the patient's normal course is. Care should be patient-centered, alarm limits should be set according to each patient's condition, and if necessary, settings should be changed according to the patient's condition and new normal. I am bothered by alarms and my mind is exhausted by dan Methods such as turning off the alarm thinking that it produces false signals, raducong e macare

the sound level to a minimum value, or keeping the alarm limits in wide ranges, can be very dangerous” (P2, 16years).

5.2.1.2 | Reducing Unnecessary, Unactionable Alarms. Participants stated that every alarm had a meaning and that not responding to an alarm by their colleagues increased both

cognitive burden and workload. Participants expressed this situation as follows: “...not responding to alarms that go off brings me an extra workload. All those sounds have a meaning. At least we need to go and see whether it is important and whether there is anything we can do at that moment” (P11, 6years). “...We have experienced many times that when alarms are responded to in time and the situation is corrected, even possible arrests can be prevented. In other words, if the necessary interventions are made when the alarms first start to give a warning, we get very successful results” (P2, 16years).

TABLE 2 | Participants' Alarm Fatigue Scale item score averages.

Alarm Fatigue Scale items	\bar{X}	SD	Min	Max
I usually hear a certain amount of noise in the environment/clinic	2.88	1.02	0	4
The heavy workload on some shifts prevents me from responding quickly to alarms	2.30	1.11	0	4
I am more sensitive to alarm sounds when I am upset and nervous	1.93	1.26	0	4
Alarm sounds make me angry	1.79	1.23	0	4
When alarms go off repeatedly and continuously, I lose my patience	1.45	1.28	0	4
Alarm sounds prevent me from focusing on my professional duties	1.37	1.23	0	4
I turn off alarms at the beginning of each shift	0.91	1.32	0	4
When alarms go off repeatedly, I become indifferent to them	0.79	1.11	0	4
During visiting hours, I pay less attention to equipment alarms	0.61	1.07	0	4
Total points	14.03	7.01	0	36

5.2.1.3 | Mentor Nurses' Positive Alarm Management Approaches. More than half of the participants emphasised that mentor nurses helped those who were new to intensive care so that they gained awareness of alarm management. One participant expressed this situation as follows: “Nurses who become desensitized to alarms affect patient safety 100%. Many of my nurse friends and I make an effort to prevent this... We say, ‘Check why the alarm is signaling... Alarms definitely have a meaning... Be sensitive to every kind of alarm and check it” (P5, 15years). Another participant described the situation as follows: “Our colleagues who are new to the profession get agitated by alarm sounds. It takes time for them to understand where each sound is coming from and what it means and to gain awareness. This takes about three years” (P13, 9years). One participant stated that mentor nurses acted as role models for their novice colleagues in acquiring alarm management skills and that they first did the right interventions themselves to show the novices. “We first make the necessary interventions ourselves to prevent alarm fatigue and desensitization. We mentor our colleagues who are new to the profession. In other words, when you, as a senior, carry out the procedures by explaining the reasons, their sensitivity inevitably increases... You draw their attention to the monitors and alarms and you show the correct intervention again when necessary; you do it, and set an example... When they observe you, it becomes their normal, too” (P3, 9years).

5.2.1.4 | Developing Alarm Management Competency and Taking Responsibility. All of the nurses, who participated in the study, emphasised that one of the approaches to preventing alarm desensitisation was orientation training on alarms given to nurses who were new to the profession/intensive

TABLE 3 | Factors associated with participants' nurses' Alarm Fatigue Scale scores.

Model	Alarm fatigue					VIF	95% Confidence interval	
	B	SE	β	t	p ^a		Lower	Upper
Total work experience in the intensive care unit	-0.507	0.182	-0.368	-2.787	0.007	1.794	-0.871	-0.143
Total weekly working hours	0.229	0.18	0.134	1.27	0.209	1.148	-0.131	0.589
Mixed shift work	-1.469	2.724	-0.068	-0.539	0.592	1.66	-6.916	3.977
Alarm management support presence	-4.276	1.428	-0.307	-2.994	0.004	1.083	-7.132	-1.42
Satisfaction	-0.062	0.031	-0.211	-2.009	0.049	1.041	-0.123	0.001

Note: $R = 0.639$; $R^2 = 0.408$, $p < 0.001$.

^aStatistically significant p values are shown in bold.

TABLE 4 | Strategies to reduce alarm fatigue in adult intensive care units.

Main themes	Sub themes	Frequency
Building an alarm management culture	Personalised alarm settings	14
	Reducing unnecessary, unactionable alarms	6
	Mentor nurses' positive alarm management approaches	12
	Developing alarm management competency and taking responsibility	14
Safe care environment	Achieving the standard patient–nurse ratio	8
	Reducing long working hours	8
	Teamwork and multidisciplinary cooperation	9
	Not silencing alarms	11
Improving the features of alarm equipment/devices	Improving technical features	8
	Customising alarm parameters	11

care. One of the participants expressed this issue as follows: “We advise them to be sensitive to all kinds of alarms and be alert. We provide training on the alarms of all devices in the intensive care unit and patient care in in-service training” (P5, 15 years). The participants also emphasised that giving written warnings to people who were desensitized to alarms could reduce insensitivity. One participant described this situation as follows: “Yes ... there are rules regarding alarms, but if there were written and tangible sanctions for those who do not care about these rules, desensitization could be reduced by half. We have friends who are desensitized to alarms. Our manager warns them, we as seniors warn them, but if that person is still desensitized to alarms and ignores them, sanctions are necessary” (P14, 4 years). Another participant's statement about this issue was as follows: “The entire team should be responsible for alarms. When they hear the alarm, they should go and check it, and do what is necessary” (P12, 14 years).

Participants stated that different solution-oriented approaches needed to be applied to prevent alarm insensitivity. One participant's statement about this issue was as follows: “All healthcare professionals working in intensive care should be sensitive to alarms. To achieve this, we can change the situation by discussing it together, reviewing our approaches, and making joint decisions. We can thus manage alarms better... Alarm management should be seen as teamwork and solution-oriented approaches should be applied” (P1, 6 years). Another participant expressed the situation as follows: “Alarm sensitivity is about responding to alarms timely... It is also important to develop the nurse's empathy skills and sensitivity to the patient” (P13, 9 years).

5.2.2 | Safe Care Environment

One of the themes elicited from the data about reducing nurses' alarm fatigue in adult intensive care units was “a safe care environment”. It consisted of the following sub-themes: achieving the standard patient–nurse ratio, reducing long working hours, teamwork and multidisciplinary cooperation and not silencing alarms.

5.2.2.1 | Achieving the Standard Patient–Nurse Ratio. More than half of the participants in the study stated that the high number of patients per nurse in intensive care units made it difficult to control patients and increased alarm fatigue and desensitisation. One participant expressed this situation as follows: “It is important to bring the patient-nurse ratio to rational levels (1:1) in intensive care units. If the number of nurses is adequate, it will be easier to control patients” (P9, 3 years). Another participant said, “Monitoring eight patients is not the same as monitoring four patients in intensive care units. It becomes difficult to tolerate the monitor sounds when working with fewer staff... You become desensitized to alarms/sounds even if this is not your intention” (P6, 17 years).

5.2.2.2 | Reducing Long Working Hours. Participants stated that long working hours reduced tolerance to alarms and increased stress levels and alarm fatigue. They expressed this situation as follows: “I work 16-17 hours in one shift. Since working hours are long, alarms affect me negatively. Hearing the same sounds constantly increases my stress levels and pushes my tolerance limits. In addition, when you realize that you have rushed to the patient's room for an unnecessary, false alarm, you feel even worse... We already work very hard and such an unnecessary increase in workload agitates people” (P9, 3 years). “If you are extremely tired, your attention is scattered. Thus, you can make mistakes... Your tolerance decreases during long working hours; you do not want to hear the alarm sound” (P11, 6 years). Participants also reported that reducing long working hours and less exposure to alarms could relieve their fatigue. One participant expressed this situation as follows: “... We can work shorter hours... We can be less exposed to alarms by increasing our time for resting” (P8, 18 years).

5.2.2.3 | Teamwork and Multidisciplinary Cooperation. Participants found multidisciplinary cooperation important in preventing alarm desensitisation and stated that the insensitivity of team members increased nurses' workload. “Each member of the multidisciplinary team working in

the intensive care unit should know all patients and be familiar with the operation of devices attached to them. Insensitivity of multidisciplinary team members increases nurses' workload" (P14, 4 years). "You should adjust the alarm limit of your patients together with the doctor according to their characteristics, condition, and treatment. This requires good teamwork" (P7, 6 years). Another participant said, "When I work in the intensive care unit, other healthcare professionals' insensitivity and ignoring the alarms returns me as too much workload, and this causes both physical and mental fatigue. When everyone takes responsibility, I am not very affected by alarms" (P11, 6 years).

5.2.2.4 | Not Silencing Alarms. More than half of the participants emphasised that not silencing alarms in adult intensive care units was important in providing a safe care environment. They said, "If everyone adjusted their alarm modes according to the patient, the sounds may be reduced, but some nurses turn off the alarm because it goes off frequently" (P1, 6 years). "... Every alarm definitely has a meaning. We should not say, 'Oh it went off a few minutes ago, it went off an hour ago, and it kept going off all the time.' We should be alert to all kinds of alarms" (P5, 15 years). Participants also emphasised that alarms that were turned off affected patient safety adversely and that sensitivity should be increased instead of turning off alarms. "Turning off the alarm or increasing the alarm limit may endanger the patient's life" (P2, 16 years). "... Alarms should not be turned off at all. Sensitivity should be increased instead" (P14, 4 years).

5.2.3 | Improving the Features of Alarm Equipment/ Devices

Data obtained from interviews with adult intensive care nurses showed that the theme of improving the features of alarm equipment/devices consisted of the sub-themes of improving technical features and customising alarm parameters.

5.2.3.1 | Improving Technical Features. Approximately two-thirds of the participants emphasised that regular checks and calibrations of devices used in intensive care units were critical for alarm management. They also pointed out that eliminating the unnecessary alarms caused by patient movement could reduce false alarms and alarm fatigue. One participant described this situation as follows: "Regular checks and calibrations of devices are very important... For example, there can be a device that detects patient movement or a device that detects/ indicates when a cable is disconnected or transmission halts" (P4, 2 years).

5.2.3.2 | Customising Alarm Parameters. Nurses reported that setting the same alarm sound for the same parameter and monitoring patient parameters from a single main monitor could be effective in reducing alarm fatigue and understanding what the warnings from the devices meant. A nurse emphasised that getting different alarms for each parameter from devices in the intensive care unit kept them alert and prevented them from missing critical alarms. "Sometimes we can hear sounds from 4-5 different devices at the bedside of a patient... It is important and necessary that the sounds are different; it keeps us more alert... Hearing the same sound all the time prevents discrimination... In fact, the sound of each device

and warning should be different, like a, b, c, d, or e. For example, when you hear the sound "a" or "b", you should understand what it means. This is much more rational" (P10, 8 years). Participants stated that monitoring patient parameters from a single main monitor in the intensive care unit could reduce alarm fatigue. One participant expressed this situation as follows: "To better manage alarms in the intensive care unit, it would be more logical and easier to connect all patient devices to a single main monitor and follow each patient's values and alarms from there" (P11, 6 years).

6 | Discussion

This study described the alarm fatigue levels of nurses working in adult intensive care units and their strategies to reduce alarm fatigue. Although alarms are not designed to interrupt nursing practices, false/unnecessary alarms can be annoying (Movahedi et al. 2023b). It is known that intensive care nurses experience moderate or higher levels of alarm fatigue (Akturan et al. 2022; Ding et al. 2023; Jeong and Kim 2023). In our study, nurses' mean score on the total alarm fatigue questionnaire was found as 14.03 ± 7.01 (min-max: 0-36), which was consistent with the literature (Table 2). The high level of alarm fatigue found in the current study indicated that additional efforts were needed to improve alarm management in critical care settings. In our study, nurses who participated in individual interviews also stated that alarms were very critical in intensive care, but they got tired of unnecessary or uncontrolled/uncontrollable alarms. Although it is known that false/unnecessary alarms cause fatigue in nurses and put patient safety at risk, alarm management in intensive care units remains an ongoing challenge. Nurses, who are the most important users of clinical alarms, need support in preventing alarm fatigue. The dimensions of alarm fatigue and how to manage and prevent it should be explored from the experiences and perspectives of nurses, who are the primary healthcare providers responsible for close patient monitoring (Movahedi et al. 2023b; Erbay Dallı and Bağcı Demirpınar 2024). Regarding this need, nurses' strategies for preventing alarm fatigue were grouped under three main themes in this study: building an alarm management culture, a safe care environment and improving the features of alarm equipment/devices (Table 4).

6.1 | Building an Alarm Management Culture

Patient monitoring is an integral part of the routine in the intensive care unit. It is considered a necessity for healthcare professionals working in the intensive care unit to customise alarm limits according to patient characteristics and conditions to reduce unnecessary alarms. Alarm limits should be adjusted by evaluating all parameters according to the patient's clinical condition (Balzer et al. 2023). In this study, all participants emphasised that unnecessary alarms and alarm fatigue could be prevented when alarm limits were adjusted specifically for the patient as follows: "...Alarm limits should be adjusted considering each patient's condition and special adjustments should be made according to the patient's condition and new normal when necessary". Despite a broad consensus that alarm thresholds for vital signs monitored as standard in the intensive care

unit should be customised according to patient-specific and situational factors, there is no standard in current alarm management. All relevant stakeholders, including hospital management and industry, should collaborate to evaluate current alarm management processes and policies (Bi et al. 2020; Movahedi et al. 2023a; American Association of Critical-Care Nurses [AACN] 2018). Considering patient and workflow characteristics in configuring alarms can make tasks easier and improve the quality of care (Mosch et al. 2024).

There were no established standards for alarm management in the adult intensive care units where this study was conducted. Nurses reported that personalised alarm settings were critical in reducing unnecessary alarms, but this could lead to some problems, as well. In the current study, the lowest-scored item on the Alarm Fatigue Questionnaire was “I ignore alarms when they go off repeatedly”. This result might indicate that critical care nurses were aware of the dangers of alarm fatigue and took measures to reduce it. As a result, considering that nurses try not to ignore alarms, the response to a large number of alarms may affect the ability of critical care nurses to provide safe and effective treatment for their patients. Healthcare providers can help reduce alarm fatigue by implementing alarm management techniques such as reducing the number of unnecessary alarms (Movahedi et al. 2023b) and using training programs on alarm management (Bi et al. 2020).

It is known that the length of clinical experience of nurses working in intensive care units is effective in alarm management and that the risk of alarm fatigue decreases as experience increases (Nyarko et al. 2023). In our study, it was observed that the alarm fatigue score of nurses who worked in intensive care for 1 to ≤ 5 years was higher than the score of those who worked for ≥ 11 years (Table 1). It was also determined that alarm fatigue decreased as the length of time nurses worked in intensive care increased (Table 3). This situation can be attributed to the fact that more experienced nurses are exposed to more alarms throughout their careers and become experts in alarm management. Clinical training and alarm management approaches of mentor nurses in intensive care units are noteworthy for novice nurses to correctly identify different alarms and respond quickly and effectively. In this study, nurses working in adult intensive care units emphasised that mentor nurses’ positive alarm management approaches were useful in reducing alarm fatigue. One statement regarding this issue was as follows: “...As mentors, first we perform the right intervention... We show and repeat it when necessary. We support them and it becomes their normal after a while”.

An important part of the alarm management strategy is the training of nurses about alarms and the assessment of alarm fatigue (Shaoru et al. 2023). In this study, participants emphasised the importance of developing alarm management competency and taking responsibility for reducing alarm fatigue. The threshold that can cause cognitive fatigue triggering alarm fatigue is subjective and is affected by individual characteristics and contextual factors (Claudio, Deb, and Diegel 2021). Educational interventions are useful in reducing excessive alarm rates and false and unactionable alarms in an environment full of alarms. Education can also improve nurses’ knowledge, perceptions and practices about alarms and alarm fatigue (Nyarko et al. 2023).

Alarm management strategies to be developed for the future should not only improve patient outcomes but also guarantee to minimise the alarm burden on healthcare professionals (Balzer et al. 2023).

6.2 | A Safe Care Environment

One of the most important problems that prevent effective alarm management is the shortage of personnel responding to alarms. For this purpose, it is recommended that an adequate number of nursing staff be employed in the intensive care units of hospitals for safe alarm management (Jeong and Kim 2023). The nurse–patient ratio and shift length are among the work-related factors affecting alarm fatigue (Claudio, Deb, and Diegel 2021). In this study, almost all of the participants (12) particularly drew attention to providing a standard nurse/patient ratio and reducing long working hours. It was also found that the alarm fatigue questionnaire scores of participants working more than 40 h a week were higher than the scores of those working 40 h or less, while the alarm fatigue levels of those working shifts on different days and at different times were higher than the levels of those working only day shift constantly ($p < 0.05$), (Table 1). However, there were also studies showing that nurses working day shifts continuously had higher alarm fatigue scores (Lewandowska et al. 2023; Nyarko et al. 2024). In this study, the lower alarm fatigue levels of nurses working only day shifts may be attributed to the fact that they knew patients better and intervened more quickly/easily as they knew the cause of the alarms. Night shift nurses are more vulnerable to alarm fatigue, which can lead to missed alarms and increased clinical stress and burnout, and can also jeopardise patient safety (Nyarko et al. 2024). In addition, the high nurse/patient ratio in shifts poses a risk in terms of alarm fatigue and patient safety (Salameh et al. 2024). The fact that the participants in this study scored high on the item “The heavy workload in some shifts prevents me from responding quickly to alarms” on the Alarm Fatigue Questionnaire (Table 2) is also important in terms of drawing attention to the importance of the issue. Therefore, managers should pay attention to the length of working hours and nurse/patient ratios, which can help reduce alarm fatigue in intensive care nurses and provide a safe care environment (Claudio, Deb, and Diegel 2021; Ruppel et al. 2023). However, the barriers and potential difficulties that may arise from manpower planning followed by upper management in the employment of nurses in healthcare institutions should be taken into account.

It is known that having policies regarding alarm management in an institution reduces the risk of alarm fatigue (Nyarko et al. 2023; Sowan 2024). In this study, it was determined that nurses who could not receive alarm management support when they needed it, especially during the night shift, had higher alarm fatigue (Table 3). Alarm fatigue can threaten patient safety by causing alarms to be silenced (Claudio, Deb, and Diegel 2021). Therefore, providing alarm management support without interruption, including during the night shift, has the potential to be effective in preventing negative patient outcomes. A study indicated that a nurse-centred alarm management system could be useful in reducing alarm fatigue (Webster and Abernathy 2020). As a result of the evaluation of these results, it is recommended that institutions create and

use evidence-based standard protocols for alarm management specific to each unit (AACN 2018).

One of the important parameters in preventing and reducing alarm fatigue in intensive care units is multidisciplinary teamwork. A lack of teamwork in intensive care is one of the main factors that reduce nurses' sensitivity to alarms and increase their workload (Movahedi et al. 2023a). In our study, it was emphasised that teamwork and multidisciplinary cooperation were critical in reducing alarm fatigue as in the following statement: "You should adjust your patient's alarm limit ... from time to time with other team members. This requires good teamwork". It was also noted that the insensitivity of team members increased nurses' workload. It is recommended to use an algorithm protocol created with a multidisciplinary team to prevent alarm fatigue in intensive care units (Nyarko et al. 2023). Managers of health-care institutions should not forget that there may be barriers to the effectiveness of multidisciplinary teams, such as inadequate decision-making, inadequate problem-solving skills, a lack of communication between team members and role conflicts.

Failure of doctors and nurses working in intensive care units to monitor patients even for a short time is considered "gross negligence". It is very important not to silence alarms so that life-threatening situations do not remain unnoticed for a long time (Lobo et al. 2024; Movahedi et al. 2023b; Nyarko et al. 2023). In this study, participants stated that it was vital not to silence alarms to provide a safe care environment in intensive care units and that alarms that were turned off affected patient safety negatively. Participants scored low on the item "I turn off alarms at the beginning of every shift" on the Alarm Fatigue Questionnaire, which indicated that despite experiencing alarm fatigue, they accepted that alarms informed them about changes in patient's condition and were important. In addition, participants emphasised that instead of turning off alarms in intensive care units, sensitivity to alarms needed to be increased. One statement about this issue was as follows: "...Alarms should not be turned off at all; sensitivity should be increased".

6.3 | Improving the Features of Alarm Equipment/Devices

Alarm fatigue is critical for patient and staff safety (Seifert et al. 2021), and approaches to prevention should also be multidisciplinary (Chromik et al. 2022). Cooperation between technical, human and organisational factors is important in alarm management programs (Dee et al. 2022). The opinions of nurses who are users of alarm devices, especially in intensive care units, on this issue and their suggestions for improving the warning parameters are very important (Agha-Mir-Salim et al. 2024). In this study, nurses emphasised the improvement of technical features of alarm equipment and devices saying, "...there can be a device that detects patient movement or a device that detects/indicates when a cable is disconnected or transmission halts". It has been recommended to integrate algorithms that analyse the entire system and increase the measurement sensitivity to reduce alarm fatigue (Webster and Abernathy 2020).

It is known that developing different alarm sounds for different situations in intensive care units, availability of a central

monitoring system and easy access to technical support can reduce nurses' alarm fatigue (Regmi et al. 2023). In this study, adult intensive care nurses drew attention to the customisation of warning parameters to reduce alarm fatigue. They also reported that using the same sound for the same parameter to understand what the alerts from the devices meant and monitoring the parameters related to the patients from a single main monitor could be effective in reducing alarm fatigue. Some studies (Claudio, Deb, and Diegel 2021; Webster and Abernathy 2020) are consistent with our results. To reduce unnecessary alarms in intensive care units and to prevent the silencing of important alarms, it may be recommended to improve the technical specifications of alarm devices and customise the warning parameters. Alarm fatigue can affect nurses' patient care performance in intensive care units and lead to situations that threaten patient safety. Therefore, alarm fatigue has been defined as an important patient safety problem (Gündoğan and Erdağı Oral 2023; JCI 2023; Lobo et al. 2024; Salameh et al. 2024). Healthcare providers should develop and implement alarm management systems that protect patient and employee safety with a multidisciplinary team that includes all stakeholders, including nurses, to reduce alarm fatigue. The study results revealed the need for systematic consideration of strategies for reducing alarm fatigue. Reducing long working hours in intensive care units, establishing routine working hours instead of working shifts on different days and times, developing teamwork and providing a safe care environment following standards can be suggested as strategies to reduce alarm fatigue at the institutional level. It is thought that these strategies can also increase patient safety and employee satisfaction, which is an important quality indicator, and ultimately create a healthier and more durable nursing workforce. Another strategy could be to develop the technical features of existing devices and design new devices with companies that develop alarm devices, by ensuring multidisciplinary team collaboration, including nurses. Among the alarm fatigue prevention strategies that emerged in our study, "mentor nurses' positive alarm management approaches, developing alarm management competence and taking responsibility, and establishing routine working hours in a way that care is not interrupted" constitute new approaches in addition to existing alarm management interventions. Moreover, "customized alarm settings, reducing unnecessary/uninterventionable alarms, ensuring a standard patient/nurse ratio, reducing long working hours, teamwork and multidisciplinary collaboration, not silencing alarms, improving the technical specifications of devices, and customizing alert parameters", which are among the current alarm management strategies (AACN 2018, 2023), are important practices in terms of showing the sensitivity of adult intensive care nurses to the issue.

6.4 | Strengths and Limitations

This study is valuable in terms of revealing the alarm fatigue levels of nurses working in adult intensive care units and their strategies to prevent fatigue. It has several limitations. First, although the study was conducted in a large university hospital, it is single-centre. Second, since the quantitative part of the study had a cross-sectional design, it was difficult to establish a causal relationship between alarm fatigue and nurses' characteristics. Third, since the measurement of alarm fatigue was performed

only once (based on a single occasion), it may reflect participants' perspectives only on that day, not the complex nature of alarm fatigue. Due to the nature of the qualitative study, our results cannot be generalised to a population. The interviews were conducted in Turkish and then translated into English. Another limitation of the study was the loss of meaning that might have occurred during translation. However, due to the widespread use of alarm devices in intensive care settings, the results of this research may contribute to the development and implementation of strategies to prevent alarm fatigue in healthcare settings in other countries.

6.5 | Implications for Policy and Practice

To reduce/prevent alarm fatigue in healthcare professionals, it can be recommended that

- proactive strategies, such as building an alarm management culture, increasing employee satisfaction, providing a safe care environment and improving the features of alarm devices, should be created and implemented,
- an evidence-based alarm management program should be designed and used with a multidisciplinary team including nurses,
- and that healthcare institutions should integrate artificial intelligence technologies into the available system to evaluate their alarm policies and procedures and achieve more efficient alarm management.

6.6 | Recommendations for Future Research

In future research, it can be recommended that

- an alarm management program that includes intensive care nurses should be developed to reduce alarm fatigue and evaluate its effectiveness and
- randomised controlled studies with high evidence levels on the implementation of alarm management programs should be conducted.

7 | Conclusion

As digital technology is integrated more in healthcare delivery, alarm fatigue threatens patient safety and becomes a growing problem. This study provides an in-depth understanding of the alarm fatigue levels of nurses working in adult intensive care units and their strategies to reduce fatigue. The strategies put forward by intensive care nurses in the study as “building an alarm management culture, a safe care environment, and improving features of alarm devices” to reduce alarm fatigue may also provide important guidance for future intervention programs. Managers should develop nurses' alarm management skills and raise awareness of alarm-related problems. Institutions should monitor intensive care nurses' alarm fatigue levels and develop proactive strategies with multidisciplinary teams to reduce/prevent alarm fatigue by creating a safe care environment, building

an alarm management culture and improving the features of alarm devices.

Author Contributions

Study conception and design: F.C., A.T.C. and A.U. Data collection: A.U. and A.T.C. Data analysis and interpretation: F.C., A.U. and A.T.C. (statistical counselling was obtained during the quantitative phase of the study [the statistics were checked prior to submission by an expert statistician; Name: Başak Oğuz; Email address: oguzbsk@gmail.com]). Drafting of the article: A.U., A.T.C. and F.C. Critical revision of the article: F.C., A.U. and A.T.C. We are confirming that all authors meet the authorship criteria and that all authors are in agreement with the content of the manuscript.

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Ethics Statement

The research was conducted in accordance with the principles of the Declaration of Helsinki. Before starting the research, approval was obtained from the Clinical Research Ethics Committee of the relevant institution (0904504/269) and permission was obtained from the institution where the research was conducted (E-26708535-900-127503).

Consent

Before starting the research, “Informed Consent” was obtained from the participants.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data supporting the findings of this study can be obtained from the corresponding author upon the request of the editor or the referees. The data are not publicly available due to privacy or ethical restrictions.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.