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REVIEW

Interventions to address alarm fatigue of critical care nurses – a scoping review

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Abstract

Aim: Nurses in intensive care units are confronted with a multitude of alarms and noises every day, which can lead to alarm fatigue. Various interventions have already been investigated to reduce or prevent this. The aim of this review is to provide an overview of empirically investigated interventions to counteract alarm fatigue in critical care nurses. *Design:* A scoping review. *Methods:* We conducted a scoping review and carried out literature searches in Medline, Cochrane Library, and CINAHL. In addition, we performed manual searches in LIVIVO and Google Scholar, as well as citation searching. We included studies on interventions aimed at reducing existing alarm fatigue or preventing potential alarm fatigue among nurses working in intensive care units. Following title, abstract, and full-text screening, data were extracted and synthesized using an inductive approach. *Results:* Seventeen studies met the inclusion criteria. The included studies were categorized into six clusters: "process interventions" (n = 8), "technological interventions" (n = 7), "training courses" (n = 7), "alarm individualization" (n = 11), "memory aids" (n = 6), and "intervention bundles" (n = 11). The investigated outcomes were divided into alarm fatigue (n = 8) and etiological factors of alarm fatigue (n = 9). *Conclusion:* Current studies on interventions against alarm fatigue are heterogeneous and difficult to compare. Future research should rely on controlled experimental designs to ensure comparability between studies.

Keywords: alarm fatigue, alert fatigue, intensive care unit, monitor, noise, nursing.

Introduction

Worldwide, the number of patients in intensive care units (ICU) and the complexity of their care needs are increasing (Garland et al., 2013; Iwashita et al., 2018; Vincent, 2013). During their treatment, patients are usually monitored and receive infusions, nutrition, and organ support through various devices.

The high occupancy rate of intensive care beds and the devices used lead to a significant number of alarms in the ICU. On average, between 150 and 350 alarms are generated per patient per day (Sendelbach & Funk, 2013), which can be up to 87.4 decibels (dB) in volume (Alduais & Salama, 2019).

Frequent exposure to a large number of loud alarms can cause alarm fatigue. This is defined as "sensory overload when clinicians are exposed to an excessive number of alarms, which can result in desensitization to alarms and missed alarms" (Sendelbach & Funk, 2013, p. 378).

Today, alarm fatigue is an international problem. Studies from various countries (e.g., China, Italy, Poland, and South Korea) indicate that critical care nurses – who are typically the first recipients of alarms – report medium to high scores on the Alarm Fatigue Questionnaire (AFQ) and other instruments (Carelli et al., 2022; Ding et al., 2023; Jeong & Kim, 2023; Lewandowska et al., 2023; Regmi et al., 2023; Seok et al., 2023). In addition, men over 30 years of age and individuals with greater professional experience report higher levels of alarm fatigue (Alkubati et al., 2024).

Missed alarm responses have different consequences for healthcare providers and patients. They can reduce confidence in alarm systems, negatively affect patient care, interrupt recovery, and lead to high levels of dissatisfaction with treatment (Casey et al., 2018; Lewandowska et al., 2023; Ruppel et al., 2023; Wilken et al., 2017).

As a result, alarm fatigue has received increasing attention in recent years. Most studies have focused primarily on patient and provider safety (Albanowski et al., 2023). However, nursing staff have rarely been included in alarm research or in the development of related models (Agha-Mir-Salim et al., 2024).

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In addition, several interventions have been studied to reduce or prevent alarm fatigue among intensive care nurses. What is still missing, however, is a comprehensive overview of the existing evidence. Information on which interventions have already been developed and empirically evaluated remains limited.

Aim

The aim of this study was to provide an overview of empirically investigated interventions designed to counteract alarm fatigue in critical care nurses. In addition, these interventions were analyzed and categorized to gain insight into the underlying research logic. Finally, gaps in the literature and directions for future research were identified. To this end, the study addresses the following research question: "Which interventions against alarm fatigue in critical care nurses have already been investigated?".

Methods

Design

To achieve the aims of this study, we conducted a scoping review (ScR) following current methodological recommendations (Peters et al., 2020; 2021). This design is particularly suitable because it allows researchers to map the existing body of knowledge on a specific topic and to identify research activities and emerging trends.

The abstract of this review is presented in accordance with the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Page et al., 2021). The main body follows the PRISMA-ScR reporting guidelines (Tricco et al., 2018).

In accordance with methodological recommendations (Page et al., 2021; Peters et al., 2022), we developed and registered a review protocol on the Open Science Framework in July 2024 (https://doi.org/10.17605/OSF.IO/JQH7Z).

Eligibility criteria

The PCC framework (participants, concept, context) was used to define the inclusion criteria, as recommended for scoping reviews (Peters et al., 2020). For this review, the population was defined as nurses and nursing assistants. Studies involving other healthcare professionals (e.g., physiotherapists, physicians) were excluded.

The concept of interest was alarm fatigue. Consistent with the definition provided in the background, we included interventions aimed at reducing existing alarm fatigue or preventing its development. Articles focusing solely on prevalence, causal mechanisms, or consequences were excluded.

Intensive care units in acute care hospitals were the context of interest for this review. Nurses with alarm fatigue included in the studies were required to work in an intensive care unit. Studies conducted exclusively in step-down units, intermediate care units, or general wards were consistently excluded.

In addition, we included only peer-reviewed journal articles published in German or English. Grey literature, nonscientific articles, and studies that did not provide sufficient detail on their methodology were excluded.

Search strategy

To identify relevant studies, we searched three databases – Medline (via PubMed), Cochrane Library, and the Cumulative Index to Nursing and Allied Health Literature (CINAHL, via EBSCOhost) – initially in June 2024 and updated the search in September 2025. Relevant keywords and synonyms were identified through preliminary searches, and the final search strings were reviewed and approved by the research team in accordance with the PRESS guideline (McGowan et al., 2016).

To complement our database search and identify potentially missed references, we conducted additional searches. First, we searched by hand (Page et al., 2021) in LIVIVO and Google Scholar. Second, we carried out citation searching (Hirt et al., 2024) with 21 studies identified in the systematic searches. The final search strings and their results are to be found in Additional file 1 (https://h7.cl/1nw7n).

Study selection inc. PRISMA flow diagram

Two reviewers (MS, FS) conducted blinded screening of titles, abstracts, and full texts using the Rayyan web application. Any conflicts that arose during the screening process were resolved through discussion with a third reviewer (LB).

Overall, our search yielded 491 records. The systematic search of Medline (via PubMed), Cochrane Library, and CINAHL (via EBSCOhost) produced 489 records, and the additional hand and citation searches identified two more. After removing duplicates and excluding 380 studies during title and abstract screening, 30 full-text articles were assessed. Of these, 13 were further excluded (see Additional File 2; https://h7.cl/1nw7n). Ultimately, 17 studies were included in this scoping review. The complete search and screening process is illustrated in Figure 1.

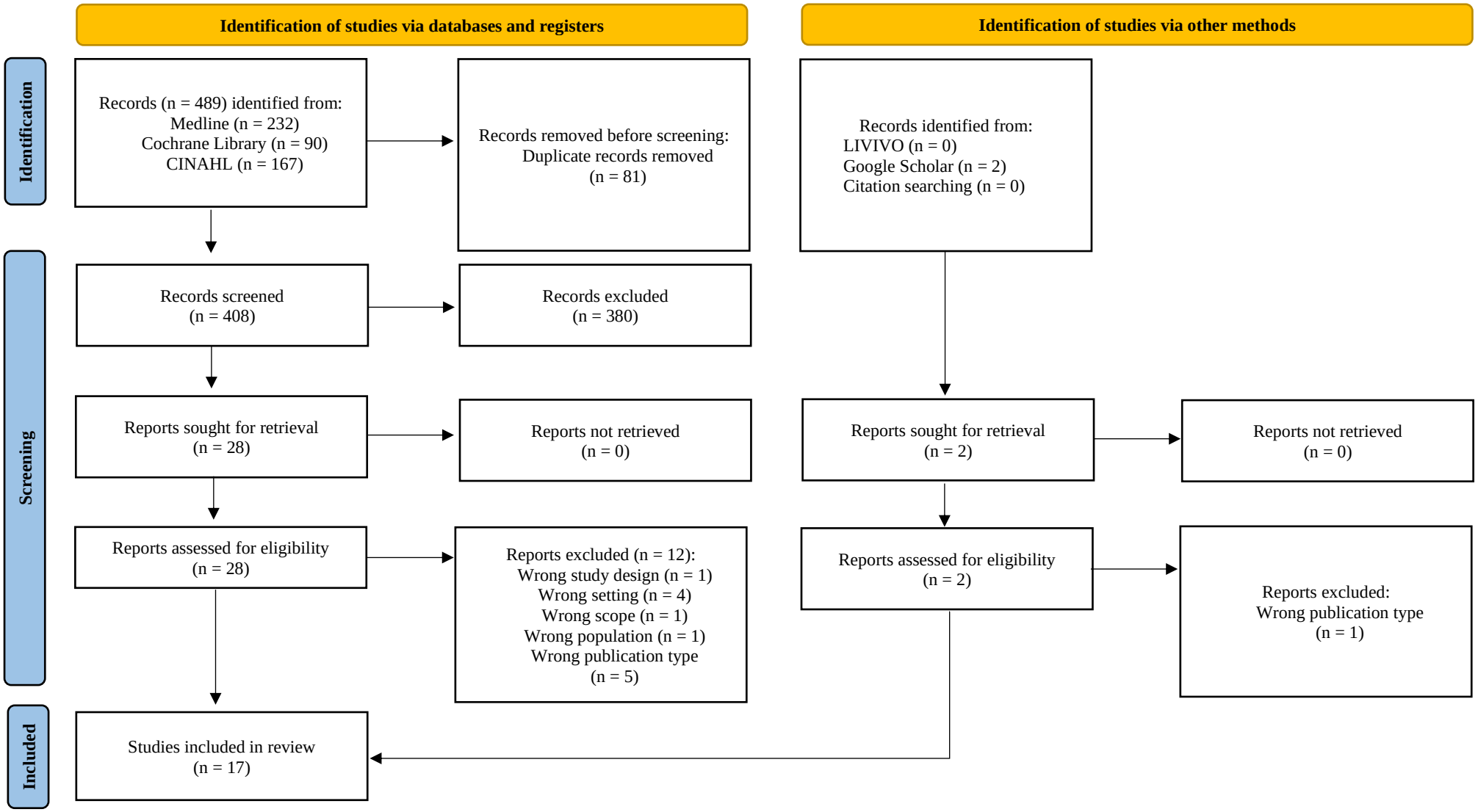

Figure 1 PRISMA flow diagram of the search and screening process (Page et al., 2021)

Evaluation of quality of articles

As specified in the methodological guidelines, the analysis of study quality is optional in scoping reviews (Peters et al., 2020; Tricco et al., 2018). In line with our aim of presenting the current evidence base without comparing the effectiveness of individual interventions, we have refrained from assessing the quality of the studies in this review.

Data extraction

To extract data, we developed a table in Microsoft Excel. We initially analyzed three studies to ensure that all relevant information could be captured. After confirming this approach, two authors (MS, FS) reviewed the remaining studies and extracted the data. The extracted data were then compared for consistency, and the tables were merged. Any conflicts were resolved through consultation with a third reviewer (LB).

Specifically, we extracted information on the authors, year of publication, and study design. In addition, we collected data on the study population, setting, and the interventions implemented. Finally, we extracted the investigated outcomes and the reported results.

To analyze and synthesize the extracted data, we followed current methodological recommendations (Pollock et al., 2023), using an inductive approach. Specifically, we performed open coding of the results, developed a framework, organized the data, and ultimately categorized it into clusters (Pollock et al., 2023).

Results

Characteristics of sources of evidence

The included studies were published between 2014 and 2024 and are mostly from the United States of America (n = 12). Further studies were conducted in the Netherlands (n = 2), Egypt (n = 1), China (n = 1) and Iran (n = 1). The most frequently used study design was the quasi-experimental design (n = 15), followed by one randomized controlled trial and one quality improvement project.

The number of nursing staff included in the studies ranged from 6 to 130. All participants worked in ICUs with various specializations (e.g., medical, surgical, neonatal, cardiac). Unit sizes also varied, ranging from 8 to 56 beds. Further details on the included studies are provided in Table 1.

Synthesis of interventions

In our data analysis, we grouped the interventions into six main clusters: process interventions, technological interventions, training courses, alarm individualization, memory aids, and intervention bundles. Detailed information on the interventions, outcomes, and results of the included studies can be found in Additional File 3 (https://h7.cl/1nw7n). The clusters are described in the following sections.

Intervention cluster 1 – Process interventions

Process interventions were examined in a total of eight studies and aimed to modify the organizational structure of clinical care by intervening directly in care processes. Examples included adapting workflows, changing ECG electrodes at the beginning of each shift (Bosma & Christopher, 2023; Leigher et al., 2020; Lewis & Oster, 2019), updating organizational guidelines, or consistently communicating alarm data (Arkilic et al., 2024; Gorisek et al., 2021; Ketko et al., 2015; Konkani et al., 2014; Varisco et al., 2021).

Intervention cluster 2 – Technological interventions

Changes to ICU software or hardware were examined in seven studies. These interventions involved adapting the use of technical devices, such as mobile pagers or handheld devices for displaying alarms (Allan et al., 2017; Broer et al., 2024; Ketko et al., 2015; Konkani et al., 2014; Ruppel et al., 2018; Sowan et al., 2016; Varisco et al., 2021).

Intervention cluster 3 – Training courses

Training courses and staff education sessions, delivered using various methods and tools, were offered in ten studies to provide new or refresher information on alarm management (Ahmad & Younes, 2023; Allan et al., 2017; Arkilic et al., 2024; Bi et al., 2020; Bosma & Christopher, 2023; Brantley et al., 2016; Gorisek et al., 2021; Lewis & Oster, 2019; Seifert et al., 2021; Varisco et al., 2021).

Intervention cluster 4 – Alarm individualization

Eleven studies conducted in ICUs with frequently standardized alarm limits examined the effects of individualizing patient alarms, such as adjusting SpO_2 limits for patients with COPD (Allan et al., 2017; Arkilic et al., 2024; Bosma & Christopher, 2023; Gorisek et al., 2021; Ketko et al., 2015; Konkani et al., 2014; Lewis & Oster, 2019; Seifert et al., 2021; Sowan et al., 2016; Varisco et al., 2021; Yousefinya et al., 2021).

Intervention cluster 5 – Memory aids

To maintain awareness of targeted alarm management, six studies employed memory aids such as posters or information flyers (Arkilic et al., 2024; Gorisek et al., 2021; Konkani et al., 2014; Seifert et al., 2021; Varisco et al., 2021; Yousefinya et al., 2021).

Table 1 Characteristics of included studies

Nr.	Author, Year	Study design	Population	Setting
01	Ahmad & Younes, 2023	Quasiexperimental study	30 ICU nurses	2 ICUs with 28 beds, Egypt
02	Allan et al., 2017	Quasiexperimental study	23 ICU nurses	18-bed cardiac and vascular surgery ICU, USA
03	Arkilic et al., 2024	Quality improvement project	24 ICU nurses pre-, 5 ICU nurses post-intervention	24-bed cardiovascular, thoracic surgical ICU, USA
04	Bi et al., 2020	RCT	93 ICU nurses (47 intervention, 46 control)	Department of critical care, China
05	Bosma & Christopher, 2023	Quasiexperimental study	115 ICU nurses	27-bed surgical ICU, USA
06	Brantley et al., 2016	Quasiexperimental study	22 ICU nurses	20-bed medical ICU, USA
07	Broer et al., 2024	Quasiexperimental study	16 patients and 26 to 27 nurses per day over 180 days	25-bed NICU, Netherlands
08	Gorisek et al., 2021	Quasiexperimental study	ICU Nurses, nursing assistants	21-bed burn ICU, academic medical center, USA
09	Ketko et al., 2015	Quasiexperimental study	N = 69, no further data	46-bed NICU, USA
10	Konkani et al., 2014	Quasiexperimental study	6 nurses	8-bed pediatric ICU, USA
11	Leigher et al., 2020	Quasiexperimental study	62 patients (32 intervention, 30 control)	Medical-surgical ICU, USA
12	Lewis & Oster, 2019	Quasiexperimental study	74 Nurses in EP. Survey: 35 Pre, 18 Post	36-bed ICU, USA
13	Ruppel et al., 2018	Quasiexperimental study	130 nurses (28 pre & post survey; 66 pre; 44 post)	56-bed medical ICU (15 step-down beds), USA
14	Seifert et al., 2021	Quasiexperimental study	60 nurses, 5 ANPs; survey: 29 pre, 25 post	15-bed medical-surgical ICU, USA
15	Sowan et al., 2016	Quasiexperimental study	39 nurses pre; 24 post	20-bed transplant-cardiac ICU, USA
16	Varisco et al., 2021	Quasiexperimental study	33 nurses pre, 31 post	18-bed family NICU, Netherlands
17	Yousefinya et al., 2021	Quasiexperimental study	60 nurses (12 students)	ICU, Iran

ANP – advanced nursing practitioners; EP – educational program; ICU – intensive care unit; NICU – neonatal intensive care unit; Nr. – number; RCT – randomized controlled trial

Intervention cluster 6 – Intervention bundles

An additional eleven studies combined at least two of the interventions described above to address alarm fatigue (Allan et al., 2017; Arkilic et al., 2024; Bosma & Christopher, 2023; Gorisek et al., 2021; Ketko et al., 2015; Konkani et al., 2014; Lewis & Oster, 2019; Seifert et al., 2021; Sowan et al., 2016; Varisco et al., 2021; Yousefinya et al., 2021). These interventions were implemented simultaneously, consecutively, or in combination, as exemplified by the CEASE bundle (Communication, Electrodes, Appropriateness, Setup, Education).

Synthesis of outcomes

In our data analysis, we grouped the investigated outcomes into two main clusters: alarm fatigue and etiological factors of alarm fatigue. The outcomes were assessed using various methods, including questionnaires, monitor evaluations, as well as measurements of volume levels and staff responses. These are described in the following sections.

Outcomes cluster 1 – Alarm fatigue

A total of eight studies examined alarm fatigue directly as an outcome (Ahmad & Younes, 2023; Allan et al., 2017; Arkilic et al., 2024; Bi et al., 2020; Bosma & Christopher, 2023; Ketko et al., 2015; Seifert et al., 2021; Sowan et al., 2016). This was assessed in seven studies using questionnaires and in one study using a multidisciplinary survey (Ketko et al., 2015).

Specifically, two studies used the Nurses' Alarm Fatigue Questionnaire (Ahmad & Younes, 2023; Seifert et al., 2021), one study applied the Alarm Fatigue Questionnaire (Bi et al., 2020), one study used the Clinical Alarm Survey from the Healthcare Technology Foundation (Bosma & Christopher, 2023), one study used an adapted version of the Clinical Alarm Survey (Sowan et al., 2016), and three studies developed their own questionnaires (Ahmad & Younes, 2023; Allan et al., 2017; Arkilic et al., 2024).

Outcomes cluster 2 – Etiological factors of alarm fatigue

An additional nine studies examined etiological factors that contribute to alarm fatigue (Brantley et al., 2016; Broer et al., 2024; Gorisek et al., 2021; Konkani et al., 2014; Leigher et al., 2020; Lewis & Oster, 2019; Ruppel et al., 2018; Varisco et al., 2021; Yousefinya et al., 2021). Data collected included alarm records, ward volume levels and their variations, patient data, and staff behavior and responses.

Findings on the effectiveness of interventions

The included studies suggested that the investigated interventions influenced alarm fatigue. Twelve of the 17 studies reported an overall reduction in alarm fatigue following implementation of the interventions (Ahmad & Younes, 2023; Allan et al., 2017; Bi et al., 2020; Brantley et al., 2016; Gorisek et al., 2021; Leigher et al., 2020; Lewis & Oster, 2019; Ruppel et al., 2018; Seifert et al., 2021; Sowan et al., 2016; Varisco et al., 2021; Yousefinya et al., 2021). However, this reduction reached statistical significance in only three studies (Ahmad & Younes, 2023; Bi et al., 2020; Bosma & Christopher, 2023).

Findings regarding the number of alarms varied across studies. While most reported a decrease in the total number of alarms, three studies observed an overall increase (Arkilic et al., 2024; Broer et al., 2024; Lewis & Oster, 2019).

Discussion

Summary of evidence

The aim of this study was to provide an overview of interventions investigated to counteract alarm fatigue in critical care nurses. To this end, we conducted a scoping review with comprehensive literature searches and ultimately included 17 studies reporting on empirically evaluated interventions.

These interventions were grouped into six clusters: process interventions, technological interventions, training courses, alarm individualization, memory aids, and intervention bundles. The clusters differed in scope and in the studies included. While some addressed specific, individual interventions, the CEASE bundle, for example, incorporated all of the other interventions (Bosma & Christopher, 2023; Lewis & Oster, 2019).

This raised the question of whether these interventions addressed all relevant aspects of alarm fatigue. Considerable knowledge now exists regarding its etiology, manifestations, and potential outcomes (Michels et al., 2025). While important factors such as lack of knowledge, unnecessary alarms, or oversensitivity (Wilken et al., 2017) have already been addressed, the interventions identified in this review did not target causal factors such as psychosocial working conditions or individual traits described by Michels et al. (2025).

An important factor that was not sufficiently addressed in the included intervention studies is the heterogeneity of the nursing staff. Nurses already differ considerably in their familial, socio-economic, and ethnic backgrounds during training (Salamonson et al., 2012). This diversity

is also reflected in the heterogeneity of care provision, as well as in variations in skills and grade mix. A more detailed analysis shows that individuals with different backgrounds and qualifications experience varying levels of compassion fatigue and burnout (Zhang et al., 2018). It remains unclear whether all nurses face the same risk of alarm fatigue and, consequently, the same need for interventions.

As some of the included studies have shown, individualizing alarms is of central importance. Not every patient exhibits the same alarm patterns; even patients with the same condition may generate different alarms, and these differences are even greater across diverse populations (Harris et al., 2017). This variability makes standardizing interventions in this area particularly challenging.

The studies also examined a range of outcomes. In addition to etiological factors, such as alarm frequency and noise, alarm fatigue itself was assessed. However, no standardized approach was used; studies employed different validated instruments or self-developed questionnaires. This heterogeneity makes comparison of results difficult and limits the conclusions that can be drawn.

The searches revealed that the relationship between alarm fatigue and nurses has been the primary focus of research to date. When matched with the NANDA classification, the nursing diagnoses Excessive Fatigue Burden and Ineffective Fatigue Self-Management are particularly relevant. These diagnoses identify individuals in demanding occupations as a high-risk population and highlight potential consequences such as delayed reactions, disengagement from the environment, and impaired motivation and sleep (Herdman et al., 2024).

This underscores the importance of preventing and promptly addressing alarm fatigue. It also highlights that patients can be indirectly affected by alarm fatigue. Research indicates that nurses' fatigue can compromise patient safety (Wilken et al., 2017) and, in some cases, contribute to life-threatening situations (Alsuyayfi & Alanazi, 2022).

Limitation of study

This review had several limitations. Only studies published in German and English were included, so relevant research in other languages may have been missed, potentially limiting the comprehensiveness of the review. Additionally, the authors did not assess study quality. Although this approach aligns with the methodological recommendations of Peters et al. (2020), it is important to acknowledge.

Finally, although we sought the clearest possible eligibility criteria, the included studies were heterogeneous in terms of study design, setting, population, interventions, and outcomes. This heterogeneity also limits the interpretability and generalizability of the review's findings.

Conclusion

This scoping review provides an important overview of interventions that have been investigated to reduce alarm fatigue in critical care nurses. However, these interventions differ substantially and demonstrate varying degrees of effectiveness. Assessment across the different outcomes also revealed notable differences. Based on this evidence, it is not yet possible to make clear recommendations for a specific intervention.

To enable stronger conclusions and facilitate comparison between studies, larger randomized controlled trials are needed in this field. In addition, standardized assessment tools should be used to ensure comparable endpoints. The relationship between alarm fatigue and patient outcomes should also be investigated in greater detail to inform effective interventions.

In addition, given its high prevalence, greater global awareness of alarm fatigue is strongly recommended. Targeted interventions to prevent and reduce alarm fatigue among nurses should be tested and implemented in every ICU.

Ethical aspects and conflict of interest

Ethical approval was not necessary for this literature review. The authors have declared no conflict of interest.

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Author contributions

Conception and design (MS, CR, LB, FS), data analysis and interpretation (MS, CR, LB, FS), manuscript draft (MS, CR, LB, FS), critical revision of the manuscript (MS, CR, LB, FS), final approval of the manuscript (MS, CR, LB, FS).

References

Agha-Mir-Salim, L., McCullum, L., Dähnert, E., Scheel, Y.-D., Wilson, A., Carpio, M., Chan, C., Lo, C., Maher, L., Dressler, C., Balzer, F., Celi, L. A., Poncette, A.-S., & Pelter, M. M. (2024). Interdisciplinary collaboration in critical care alarm research: a bibliometric analysis. *International Journal of Medical Informatics*, *181*, 105285. https://doi.org/10.1016/j.ijmedinf.2023.105285

Ahmad, I. M., & Younes, S. A. R (2023). Effect of implementing noise reduction interventions on sound levels and alarm fatigue in intensive care units. *Assiut Scientific Nursing Journal*, *11*(39), 192–202. https://doi.org/10.21608/asnj.2023.227191.1649

Albanowski, K., Burdick, K. J., Bonafide, C. P., Kleinpell, R., & Schlesinger, J. J. (2023). Ten years later, alarm fatigue is still a safety concern. *AACN Advanced Critical Care*, *34*(3), 189–197. https://doi.org/10.4037/aacnacc2023662

Alduais, S. A., & Salama, K. F. (2019). Assessment of ambient-noise exposure among female nurses in surgical cardiac intensive care unit. *Journal of Multidisciplinary Healthcare*, *12*, 1007–1011. https://doi.org/10.2147/JMDH.S222801

Alkubati, S. A., Alsaqri, S. H., Alrubaiee, G. G., Almoliky, M. A., Alqalah, T. A. H., Pasay-An, E., Alrasheeday, A. M., & Elsayed, S. M. (2024). Levels and factors of nurses' alarm fatigue in critical care settings in Saudi Arabia: a multicenter cross-sectional study. *Journal of Multidisciplinary Healthcare*, *17*, 793–803. https://doi.org/10.2147/JMDH.S452933

Allan, S. H., Doyle, P. A., Sapirstein, A., & Cvach, M. (2017). Data-driven implementation of alarm reduction interventions in a cardiovascular surgical ICU. *The Joint Commission Journal on Quality and Patient Safety*, *43*(2), 62–70. https://doi.org/10.1016/j.jcjq.2016.11.004

Alsuyayfi, S., & Alanazi, A. (2022). Impact of clinical alarms on patient safety from nurses' perspective. *Informatics in Medicine Unlocked*, *32*, 101047. https://doi.org/10.1016/j.imu.2022.101047

Arkilic, L. Z., Hundt, E., & Quatrara, B. (2024). Critical care alarm fatigue and monitor customization: alarm frequencies and context factors. *Critical Care Nurse*, *44*(2), 21–30. https://doi.org/10.4037/ccn2024797

Bi, J., Yin, X., Li, H., Gao, R., Zhang, Q., Zhong, T., Zan, T., Guan, B., & Li, Z. (2020). Effects of monitor alarm management training on nurses' alarm fatigue: a randomised controlled trial. *Journal of Clinical Nursing*, *29*(21–22), 4203–4216. https://doi.org/10.1111/jocn.15452

Bosma, S., & Christopher, R. (2023). Implementing a unit-based alarm management bundle for critical care nurses. *Critical Care Nurse*, *43*(2), 36–45. https://doi.org/10.4037/ccn2023418

Brantley, A., Collins-Brown, S., Kirkland, J., Knapp, M., Pressley, J., Higgins, M., & McMurtry, J. P. (2016). Clinical trial of an educational program to decrease monitor alarms in a medical intensive care unit. *AACN Advanced Critical Care*, *27*(3), 283–289. https://doi.org/10.4037/aacnacc2016110

Broer, S. D. L., Cramer, S. J. E., Tan, R. N. G. B., & Witlox, R. S. G. M. (2024). Minimising alarm pressure on a single room NICU through automated withdrawal of resolved alarms. *Acta Paediatrica*, *113*(2), 206–211. https://doi.org/10.1111/apa.17029

Carelli, L., Terzoni, S., Destrebecq, A., Formenti, P., Soumahoro, F., Esposito, A., & Ferrara, P. (2022). Alarm fatigue in nurses working in intensive care units: a multicenter study. *Work: A Journal of Prevention, Assessment & Rehabilitation*, *72*(2), 651–656. https://doi.org/10.3233/WOR-210552

Casey, S., Avalos, G., & Dowling, M. (2018). Critical care nurses' knowledge of alarm fatigue and practices towards alarms: a multicentre study. *Intensive & Critical Care Nursing*, *48*, 36–41. https://doi.org/10.1016/j.iccn.2018.05.004

Ding, S., Huang, X., Sun, R., Yang, L., Yang, X., Li, X., Liu, J., Yang, H., Zhou, H., Huang, X., Su, F., Shu, L., Zheng, X., & Wang, X. (2023). The relationship between alarm fatigue and burnout among critical care nurses: a cross-sectional study. *Nursing in Critical Care*, *28*(6), 940–947. https://doi.org/10.1111/nicc.12899

Garland, A., Olafson, K., Ramsey, C. D., Yogendran, M., & Fransoo, R. (2013). Epidemiology of critically ill patients in intensive care units: a population-based observational study. *Critical Care*, *17*(5), R212. https://doi.org/10.1186/cc13026

Gorisek, R., Mayer, C., Hicks, W. B., & Barnes, J. (2021). An evidence-based initiative to reduce alarm fatigue in a burn intensive care unit. *Critical Care Nurse*, *41*(4), 29–37. https://doi.org/10.4037/ccn2021166

Harris, P. R., Zègre-Hemsey, J. K., Schindler, D., Bai, Y., Pelter, M. M., & Hu, X. (2017). Patient characteristics associated with false arrhythmia alarms in intensive care. *Therapeutics and Clinical Risk Management*, *13*, 499–513. https://doi.org/10.2147/TCRM.S126191

Herdman, T. H., Kamitsuru, S., & Lopes, C. T. (2024). *NANDA-I International Nursing Diagnoses: Definitions and Classification 2024–2026*. Thieme Publishers. https://doi.org/10.1055/b000000928

Hirt, J., Nordhausen, T., Fuerst, T., Ewald, H., & Appenzeller-Herzog, C. (2024). Guidance on terminology, application, and reporting of citation searching: The TARCiS statement. *BMJ*, *385*, e078384. https://doi.org/10.1136/bmj-2023-078384

Iwashita, Y., Yamashita, K., Ikai, H., Sanui, M., Imai, H., & Imanaka, Y. (2018). Epidemiology of mechanically ventilated patients treated in ICU and non-ICU settings in Japan: a retrospective database study. *Critical Care*, *22*(1), 329. https://doi.org/10.1186/s13054-018-2250-3

Jeong, Y. J., & Kim, H. (2023). Critical care nurses' perceptions and practices towards clinical alarms. *Nursing in Critical Care*, *28*(1), 101–108. https://doi.org/10.1111/nicc.12751

Ketko, A. K., Martin, C. M., Nemshak, M. A., Niedner, M., & Vartanian, R. J. (2015). Balancing the tension between hyperoxia prevention and alarm fatigue in the NICU. *Pediatrics*, *136*(2), e496–504. https://doi.org/10.1542/peds.2014-1550

Konkani, A., Oakley, B., & Penprase, B. (2014). Reducing hospital ICU noise: a behavior-based approach. *Journal of Healthcare Engineering*, *5*(2), 229–246. https://doi.org/10.1260/2040-2295.5.2.229

Leigher, D., Kemppainen, P., & Neyens, D. M. (2020). Skin preparation and electrode replacement to reduce alarm fatigue in a community hospital intensive care unit. *American Journal of Critical Care*, *29*(5), 390–395. https://doi.org/10.4037/ajcc2020120

Lewandowska, K., Mędrzycka-Dąbrowska, W., Tomaszek, L., & Wujtewicz, M. (2023). Determining factors of alarm fatigue among nurses in intensive care units – a Polish pilot study. *Journal of Clinical Medicine*, *12*(9), 3120. https://doi.org/10.3390/jcm12093120

Lewis, C. L., & Oster, C. A. (2019). Research Outcomes of implementing CEASE: an innovative, nurse-driven, evidence-based, patient-customized monitoring bundle to decrease alarm fatigue in the intensive care unit/step-down unit. *Dimensions of Critical Care Nursing*, *38*(3), 160–173. https://doi.org/10.1097/DCC.0000000000000357

McGowan, J., Sampson, M., Salzwedel, D. M., Cogo, E., Foerster, V., & Lefebvre, C. (2016). Press peer review of electronic search strategies: 2015 guideline statement. *Journal of Clinical Epidemiology*, *75*, 40–46. https://doi.org/10.1016/j.jclinepi.2016.01.021

Michels, E. A. M., Gilbert, S., Koval, I., & Wekenborg, M. K. (2025). Alarm fatigue in healthcare: a scoping review of definitions, influencing factors, and mitigation strategies. *BMC Nursing*, *24*(1), 664. https://doi.org/10.1186/s12912-025-03369-2

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., . . . Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, *372*, n71. https://doi.org/10.1136/bmj.n71

Peters, M. D. J., Godfrey, C., McInerney, P., Khalil, H., Larsen, P., Marnie, C., Pollock, D., Tricco, A. C., & Munn, Z. (2022). Best practice guidance and reporting items for the development of scoping review protocols. *JBI Evidence Synthesis*, *20*(4), 953–968. https://doi.org/10.11124/JBIES-21-00242

Peters, M. D. J., Marnie, C., Colquhoun, H., Garritty, C. M., Hempel, S., Horsley, T., Langlois, E. V., Lillie, E., O'Brien, K. K., Tunçalp, Ö., Wilson, M. G., Zarin, W., & Tricco, A. C. (2021). Scoping reviews: reinforcing and advancing the methodology and application. *Systematic Reviews*, *10*(1), 263. https://doi.org/10.1186/s13643-021-01821-3

Peters, M. D. J., Marnie, C., Tricco, A. C., Pollock, D., Munn, Z., Alexander, L., McInerney, P., Godfrey, C. M., & Khalil, H. (2020). Updated methodological guidance for the conduct of scoping reviews. *JBI Evidence Synthesis*, *18*(10), 2119–2126. https://doi.org/10.11124/JBIES-20-00167

Pollock, D., Peters, M. D. J., Khalil, H., McInerney, P., Alexander, L., Tricco, A. C., Evans, C., Moraes, É. B. de, Godfrey, C. M., Pieper, D., Saran, A., Stern, C., & Munn, Z. (2023). Recommendations for the extraction, analysis, and presentation of results in scoping reviews. *JBI Evidence Synthesis*, *21*(3), 520–532. https://doi.org/10.11124/jbies-22-00123

Regmi, B., Shrestha, B., Khanal, S., Moktan, S., & Byanju, R. (2023). Alarm fatigue among nurses working in critical care setting in a tertiary hospital, Nepal. *Kathmandu University Medical Journal*, *21*(81), 28–32.

Ruppel, H., Dougherty, M., Bonafide, C. P., & Lasater, K. B. (2023). Alarm burden and the nursing care environment: a 213-hospital cross-sectional study. *BMJ Open Quality*, *12*(4). https://doi.org/10.1136/bmjoq-2023-002342

Ruppel, H., Vaux, L. de, Cooper, D., Kunz, S., Duller, B., & Funk, M. (2018). Testing physiologic monitor alarm customization software to reduce alarm rates and improve nurses' experience of alarms in a medical intensive care unit. *PloS One*, *13*(10), e0205901. https://doi.org/10.1371/journal.pone.0205901

Salamonson, Y., Ramjan, L., Lombardo, L., Lanser, L. H., Fernandez, R., & Griffiths, R. (2012). Diversity and demographic heterogeneity of Australian nursing students: a closer look. *International Nursing Review*, *59*(1), 59–65. https://doi.org/10.1111/j.1466-7657.2011.00925.x

Seifert, M., Tola, D. H., Thompson, J., McGugan, L., & Smallheer, B. (2021). Effect of bundle set interventions on physiologic alarms and alarm fatigue in an intensive care unit: a quality improvement project. *Intensive & Critical Care Nursing*, *67*, 103098. https://doi.org/10.1016/j.iccn.2021.103098

Sendelbach, S., & Funk, M. (2013). Alarm fatigue: a patient safety concern. *AACN Advanced Critical Care*, *24*(4), 378–386. https://doi.org/10.4037/NCI.0b013e3182a903f9

Seok, Y., Cho, Y., Kim, N., & Suh, E. E. (2023). Degree of alarm fatigue and mental workload of hospital nurses in intensive care units. *Nursing Reports*, *13*(3), 946–955. https://doi.org/10.3390/nursrep13030083

Sowan, A. K., Gomez, T. M., Tarriela, A. F., Reed, C. C., & Paper, B. M. (2016). Changes in default alarm settings and standard in-service are insufficient to improve alarm fatigue in an intensive care unit: a pilot project. *JMIR Human Factors*, *3*(1). https://doi.org/10.2196/humanfactors.5098

Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K. K., Colquhoun, H., Levac, D., Moher, D., Peters, M. D. J., Horsley, T., Weeks, L., Hempel, S., Akl, E. A., Chang, C., McGowan, J., Stewart, L., Hartling, L., Aldcroft, A., Wilson, M. G., Garritty, C., . . . Straus, S. E. (2018). Prisma extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Annals of Internal Medicine*, *169*(7), 467–473. https://doi.org/10.7326/M18-0850

Varisco, G., van de Mortel, H., Cabrera-Quiros, L., Atallah, L., Hueske-Kraus, D., Long, X., Cottaar, E. J., Zhan, Z., Andriessen, P., & van Pul, C. (2021). Optimisation of clinical workflow and monitor settings safely reduces alarms in the NICU. *Acta Paediatrica*, *110*(4), 1141–1150. https://doi.org/10.1111/apa.15615

Vincent, J.-L. (2013). Critical care – where have we been and where are we going? *Critical Care*, *17*(Suppl 1), S2. https://doi.org/10.1186/cc11500

Wilken, M., Hüske-Kraus, D., Klausen, A., Koch, C., Schlauch, W., & Röhrig, R. (2017). Alarm fatigue: causes and effects. *Studies in Health Technology and Informatics*, *243*, 107–111.

Yousefinya, A., Torabizadeh, C., Zand, F., Rakhshan, M., & Fararooei, M. (2021). Effectiveness of application of a manual for improvement of alarms management by nurses in intensive care units. *Investigacion y Educacion En Enfermeria*, *39*(2). https://doi.org/10.17533/udea.iee.v39n2e11

Zhang, Y.-Y., Han, W.-L., Qin, W., Yin, H.-X., Zhang, C.-F., Kong, C., & Wang, Y.-L. (2018). Extent of compassion satisfaction, compassion fatigue and burnout in nursing: a meta-analysis. *Journal of Nursing Management*, *26*(7), 810–819. https://doi.org/10.1111/jonm.12589