Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Alarm fatigue among nurses in paediatric intensive care units from a social ecological systems theory perspective: a qualitative descriptive study

Shuang Li
Shengjing Hospital of China Medical University
Jiaxin Yan
Shengjing Hospital of China Medical University
Xianjuan Cheng
Shengjing Hospital of China Medical University
Hailong Hou
Sichuan University
Yan Jiang
Shengjing Hospital of China Medical University
Fang Yang
Shengjing Hospital of China Medical University
Linxi He
1310317476@qq.com

Shengjing Hospital of China Medical University

Research Article

Keywords: Alarm fatigue, Intensive care, Nurses, Paediatrics, Patient safety, Qualitative research, Social ecological systems

Posted Date: November 18th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11525687/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Background

Nurses in paediatric intensive care units face a high risk of alarm fatigue because of the distinctive clinical and developmental characteristics of children. However, research on alarm fatigue among paediatric intensive care nurses remains limited, and systematic exploration from a social ecological systems theory perspective is lacking.

Objective

To explore the lived experiences of alarm fatigue among nurses in paediatric intensive care units and identify influencing factors across multiple ecological systems.

Design:

A theory-informed qualitative descriptive study.

Methods

From March to August 2025, semi-structured face-to-face interviews were conducted with 14 nurses working in paediatric intensive care units at four tertiary grade A hospitals in northeast China and Inner Mongolia. Data were analysed using directed content analysis that combined deductive and inductive techniques, guided by social ecological systems theory.

Results

Three themes and nine subthemes were identified. The microsystem theme, individual challenges and coping among nurses, comprised sensory overload and attentional disruption, physical and psychological disequilibrium, and experience-related differences in coping. The mesosystem theme, organisational constraints and support, comprised staffing and workforce effectiveness, the double-edged effect of teamwork mechanisms, equipment differences and maintenance management, and child-oriented technological updating and training needs. The macrosystem theme, barriers and drivers in policy, systems and culture, comprised absent or underdeveloped alarm management systems, limited incentives and support policies, and the enabling role of a patient-safety-centred healthcare culture.

Conclusions

Alarm fatigue among nurses in paediatric intensive care units is produced by interacting factors across micro, mezzo and macro systems. Sustainable improvement requires multilevel interventions that support nurses' dynamic self-regulation, strengthen organisational conditions for alarm management, and establish policy, cultural and institutional safeguards.

Background

The paediatric intensive care unit (PICU) is a core clinical setting for the treatment of critically ill children. Children admitted to PICUs are severely ill, their conditions can change rapidly, and their care depends on a range of medical devices that dynamically monitor vital signs and physiological parameters [1]. With the rapid development of critical care medicine, the number of monitoring and therapeutic devices used in PICUs has increased substantially [2]. Studies have shown that PICU nurses may need to handle hundreds of alarms during each shift, although 87.1% to 90% of alarms are not directly related to child safety [1, 3]. In other words, most alarms are non-urgent or non-actionable. Alarms are intended to alert nurses to potential risks and protect patient safety. Yet large volumes of non-actionable alarms can reduce nurses' sensitivity to critical alarms, leading to delayed responses or even missed alarms, thereby jeopardising patient safety. This phenomenon is defined as alarm fatigue [4].

As direct care providers and the primary recipients of clinical alarms, nurses are the professional group most affected by alarm fatigue. Among intensive care unit (ICU) nurses, 62.6% experience moderate to high levels of alarm fatigue [5], indicating a serious clinical problem. Compared with adult ICUs, PICUs have higher alarm frequencies and higher rates of non-actionable alarms [3, 6]. The specialised PICU environment and the characteristics of the children treated there expose nurses to a higher and more distinctive risk of alarm fatigue. Children's limited cooperation and crying or movement can generate monitoring artefacts and markedly increase non-actionable alarms [7]. In addition, children are in a period of rapid growth and development. Normal ranges for vital signs differ substantially by age, weight and developmental stage; monitor parameters that simply adopt adult standards or are set inappropriately may therefore trigger frequent false alarms [8]. PICUs also commonly use a closed, no-family-accompaniment management model. Separation from family members and exposure to an unfamiliar environment can cause fear and anxiety among children. Consequently, PICU nurses must provide daily care while also attending to children's psychological needs, leaving their workload and emotional stress persistently high [9, 10] and increasing susceptibility to alarm fatigue. Although PICU nurses face alarm fatigue risks that are higher and more complex than those of many other groups, existing studies have mainly focused on adult ICUs [11–13]. Research involving PICU nurses is scarce and predominantly quantitative [14], making it difficult to reveal nurses' lived experiences, behavioural motivations and intervention needs.

Alarm fatigue is a complex psychological and behavioural experience that develops in clinical contexts, and its influencing factors are often contextual and hidden [15]. Qualitative research is grounded in natural settings and seeks to capture experiences from participants' perspectives [16]. It can illuminate internal mechanisms and implicit factors that are difficult to identify through quantitative approaches

[17], making it appropriate for in-depth exploration of alarm fatigue among PICU nurses. At the same time, achieving long-term sustainability in interventions to reduce alarm fatigue is an important future direction. The PICU work environment is complex, and nurses' alarm fatigue is affected by individual, group and broader social factors [18, 19]. Existing interventions often focus on a single dimension, such as equipment renewal, staffing or operational training. Although these measures may temporarily alleviate alarm fatigue, they are unlikely to produce sustained improvement [20, 21]. This limitation may be explained by insufficient coordination across systems and failure to address deeper mechanisms underlying alarm fatigue.

Social ecological systems theory emphasises continuous interaction between individuals and their social environments. It conceptualises human social ecological systems as comprising micro, mezzo and macro systems, with these systems being interrelated and mutually influential [22, 23]. A key strength of this theory is its capacity to analyse comprehensively the links between individuals and environments and the interactions among systems. It therefore provides a useful framework for revealing the complexity and multidimensional sources of alarm fatigue among PICU nurses.

Guided by social ecological systems theory, this qualitative study explored the real experiences of alarm fatigue among PICU nurses and its influencing factors across micro, mezzo and macro systems levels. It also examined interactions between factors at different levels. The findings deepen understanding of alarm fatigue in PICU nurses and provide a theoretical and practical foundation for developing long-term sustainable interventions and support systems.

Methods

Design

This study used a theory-informed qualitative descriptive design. Qualitative description is a research approach grounded in the philosophical principles of naturalistic inquiry, including recognition of the inseparable and interactive nature of shared experience and human interaction. The approach is flexible and pragmatic, enabling researchers to present PICU nurses' real experiences and views of alarm fatigue faithfully and directly in their own language [24]. Unlike descriptive phenomenology, qualitative description allows participants' narrative accounts to be mapped directly onto the dimensions of a theoretical framework while remaining open to themes outside that framework [25]. The findings of qualitative descriptive studies provide a foundation for deriving richly described ideas, themes or concepts from participants and for developing practical educational or behavioural interventions. This theory-informed qualitative descriptive design was therefore appropriate for exploring the application of social ecological systems theory in this specific context.

Participants and setting

Purposive sampling was used to recruit PICU nurses from four tertiary grade A hospitals in northeast China and Inner Mongolia between March and August 2025. Inclusion criteria were: (1) being a registered nurse currently in post; (2) having worked in a PICU for at least 2 years; (3) independently caring for assigned patients; and (4) providing informed consent and voluntarily agreeing to participate. Exclusion criteria were: (1) being away from post during data collection because of sick leave, personal leave, maternity leave or other reasons; and (2) having participated in a similar interview within the previous 2 months.

Data collection

Drawing on the study by Lu et al. [26], the research team consulted experts and developed a preliminary interview guide based on social ecological systems theory. To test the appropriateness of the preliminary guide, two PICU nurses were invited to participate in face-to-face pilot interviews. The guide was revised in response to the pilot interviews and participant feedback. Clarifying prompts such as "What were you thinking at that time?" and "Can you give an example?" were added, resulting in the final semi-structured interview guide (Table 1).

Table 1
Semi-structured interview guide

No.	Question
1	Please describe in detail your experiences of alarm fatigue at work. What were your thoughts and feelings at that time?
2	How do you view the phenomenon of "alarm fatigue"? Have your views about alarm fatigue changed?
3	Based on your experience, what do you think may cause alarm fatigue?
4	In your work and life, what factors or methods help reduce alarm fatigue?
5	What difficulties and barriers have you encountered when coping with alarm fatigue? How did you overcome them? Are there still difficulties or barriers that need to be addressed?
6	Please describe the actual situation and effectiveness of alarm management in your hospital or department. What are your views or suggestions?
7	What expectations do you have for better supporting nurses' work and reducing alarm fatigue in the future?

Interviews were conducted face to face using a semi-structured format. Before each interview, the researchers explained the study purpose, methods and content, and participants signed informed consent forms. No non-participants were present during the interviews, and no repeat interviews were conducted. Interviews lasted 20 to 40 minutes. With participants' permission, all interviews were audio-recorded. Two researchers participated in the interviews. One was a nursing postgraduate student with extensive experience in qualitative data collection and was responsible for asking questions based on

the interview guide and flexibly adjusting the wording and order of questions to elicit as much information as possible. The other researcher did not ask interview questions but monitored whether potentially leading questions were used and recorded non-verbal expressions, such as tone, emotional changes and body language. These records enhanced transparency and the accuracy of interview data.

The number of participants was determined according to the principle of data saturation [27], that is, no new themes or perspectives emerged after additional participants were interviewed. In this study, two researchers independently extracted themes from the interview records. After the 12th interview, both researchers confirmed that no new themes were emerging. Two additional interviews were conducted, and no further new themes emerged. Data saturation was therefore judged to have been achieved, and 14 PICU nurses were ultimately interviewed.

Ethical considerations

Ethical approval

was obtained from the medical ethics committee of the study institution (approval details blinded for peer review). Informed consent was obtained before the study began. Participants had the right to withdraw at any point. Participants' real names were replaced by codes, and all information was treated as confidential.

Data analysis

Audio recordings were transcribed verbatim within 24 hours after each interview.Directed content analysis was used, combining deductive and inductive techniques [28]. Directed content analysis is commonly used to validate or extend an existing conceptual framework or theory [28]. Based on social ecological systems theory [22, 23], micro, mezzo and macro systems were predefined as initial coding categories. At the same time, the analysis remained open to new themes outside these categories. If meaningful content could not be assigned to the preset framework, a new coding category was added to ensure that emerging themes were grounded in participants' narratives. Combining deduction and induction enabled the findings to be theoretically informed while also remaining rooted in the language of PICU nurses [28], thereby strengthening their practical applicability.

Rigour

The research team had no direct conflict of interest with participants. The interviewer was a master's student who had received systematic training in qualitative research, which helped ensure methodological rigour and enhance credibility. Before interviews, the researchers assured participants that their information would be kept confidential, thereby helping to establish trust and support authentic data collection. To enrich data sources and ensure sample diversity and representativeness, participant selection considered sex, educational level, marital status, years of nursing experience, years of PICU experience and age. During interviews, field notes were taken to capture additional observations, and the

researchers maintained a neutral stance, avoiding unnecessary interruption and leading prompts. This manuscript was prepared in accordance with the Consolidated Criteria for Reporting Qualitative Research (COREQ) [29] to enhance transparency and reproducibility.

Results

Participant characteristics

Fourteen PICU nurses participated in formal interviews. No nurse refused participation or withdrew during the study. Participants were aged 26 to 46 years; two were men and 12 were women. Participant characteristics are shown in Table 2.

Table 2
Participant characteristics (n = 14)

Code	Age	Education	Years of nursing experience	Years of PICU experience	Marital status
N1	25–30	Master's degree	3	3	Unmarried
N2	25–30	Bachelor's degree	4	2	Unmarried
N3	25–30	Master's degree	2	2	Unmarried
N4	36–40	Bachelor's degree	16	16	Married
N5	36–40	College diploma	15	15	Married
N6	41–50	Bachelor's degree	18	17	Married
N7	36–40	Bachelor's degree	15	8	Married
N8	41–50	College diploma	22	18	Married
N9	25–30	Bachelor's degree	4	2	Unmarried
N10	31–35	Bachelor's degree	13	2	Married
N11	25–30	Master's degree	2	2	Unmarried
N12	41–50	Bachelor's degree	22	20	Married
N13	41–50	Bachelor's degree	19	17	Married
N14	36–40	Bachelor's degree	15	13	Married

Main findings

Based on in-depth interviews and analysis guided by social ecological systems theory, three themes and nine subthemes were identified (Fig. 1).

Theme 1. Micro system: individual challenges and coping among nurses

Subtheme 1.1. Sensory overload and attentional disruption

Alarm signals from monitoring devices in the PICU are diverse, and crying children, device indicator lights and changes in children's clinical signs create overlapping visual and auditory stimuli. This produces a high-intensity sensory load. Nurses are vulnerable to sensory overload, and prolonged exposure to this environment may lead the brain to filter out persistent alarm signals. Nurses described a form of "auditory numbness", in which alarms no longer immediately triggered a response, causing delayed reactions. In addition, multiple alarms often sounded simultaneously. When nurses were performing invasive procedures or managing emergencies, they also had to divide their attention to respond to unexpected alarms, resulting in continuous attentional disruption.

"Sometimes critically ill children cry, and the crying is louder than the alarm." (N1)

"There are alarms all the time. Sometimes there may really be a change in the condition, but you stop paying that much attention to the alarm." (N2)

"Listening to alarms for a long time reduces my awareness of them, so sometimes when a child has an alarm, I do not react immediately." (N4)

"Sometimes I am dealing with one critically ill child, and another child's condition is not good. If that child also has an alarm, I cannot handle it in time." (N1)

"During resuscitation, several alarms go off at the same time. You simply cannot tell which child the alarm is coming from, and it becomes very difficult to manage." (N8)

Subtheme 1.2. Physical and psychological disequilibrium

Maintaining a high level of sensitivity to alarms for long periods placed nurses under both psychological and physical overload. Nurses reported psychological disequilibrium, including tension, anxiety and mental exhaustion. They also described physical disequilibrium, such as hearing deterioration, auditory hallucinations and sleep disturbance. This disequilibrium was not limited to working hours but continued after work and even during dreams. Physical and psychological disequilibrium affected alarm recognition and contributed to delayed alarm responses.

"The children in our unit sometimes change very quickly. The psychological pressure is quite heavy because the alarms keep sounding, and you feel as if a string in your mind is always stretched tight." (N11)

"I feel that my hearing is not as good as before. Sometimes I think that hearing damage really affects my ability to distinguish patient alarms." (N8)

"After a night shift, honestly, my ears are full of all kinds of alarm sounds—the monitors, the ventilators, everything." (N11)

"I even hear alarms in my dreams. After work I still feel that alarms are ringing beside my ears." (N10)

Subtheme 1.3. Experience-related differences in coping

Many nurses stated that novice nurses often struggled to identify the source of alarms quickly and accurately because of limited experience. Confusion and uncertainty also made it difficult for them to take timely and appropriate actions. Participants reported that, as experience accumulated, they became able to distinguish different alarm sounds, prioritise alarms according to urgency, manage critical alarms first, and even predict alarms and intervene in advance. These abilities reduced alarm occurrence, improved response efficiency and relieved alarm fatigue. However, some nurses also noted that with increasing years of work, they sometimes simplified judgments based on habitual thinking, selectively ignored low-priority alarms, or even turned alarms off.

"When I first started working, if an alarm sounded I was not sure whether it was a false alarm or a change in vital signs. Sometimes it sounded and I could not even find which machine was alarming." (N1)

"Now, nurses with more experience may gradually learn through managing patients. Based on the child's condition, if a particularly severe child has a ventilator alarm or monitor alarm, I will definitely deal with that first." (N11)

"If you deal with the problem while it is still at an early stage, for example when I hear sputum in the airway, I cannot tolerate it and have to handle it immediately, even before the ventilator alarms." (N3)

"Over time, it may gradually become a behavioural habit. I just glance at the child, feel that the child seems all right, and then habitually turn the alarm off." (N10)

Theme 2. Mezzo system: organisational constraints and support

Subtheme 2.1. Staffing and workforce effectiveness

The number and acuity of patients in intensive care are uncertain. When temporary staffing gaps occurred, existing nurses had to take on additional work and pressure. When staffing levels were low, nurses prioritised emergency patients, resulting in longer response times for non-urgent alarms. Frequent night shifts disrupted nurses' biological rhythms, causing sleep deprivation and impaired cognitive function, which reduced sensitivity to monitor alarms. Long individual shifts also slowed decision-making and responses.

"Nursing staff are limited. One nurse has to care for several critically ill children, and the pressure is especially high." (N4)

"When work is extremely busy or there are two or more groups of patients being resuscitated at the same time, alarms from children with milder conditions may be overlooked." (N7)

“On night shifts, because of the biological clock, your reactions are not very sharp at that time, which leads to alarm fatigue.” (N1)

“In the latter half of the night I become very sleepy. If night-shift hours were shortened, the speed, efficiency and quality of work would definitely be different.” (N8)

“The average weekly working time is now 40 hours. It would be better to reduce the length of each shift.” (N13)

Subtheme 2.2. The double-edged effect of teamwork mechanisms

Nurses stated that effective teamwork could share pressure. They hoped colleagues would intervene when they themselves could not immediately manage an alarm, thereby improving response efficiency. However, although some units had “cooperative group” arrangements, unclear responsibility boundaries and limited knowledge of the condition of children assigned to others meant that nurses often did not dare to manage alarms for patients under another nurse’s responsibility. Participants also believed that alarm management should not rely solely on nurses; physicians’ attention to alarm systems was also important.

“Sometimes you are too busy and can only hope that other colleagues will help.” (N8)

“Colleagues in the cooperative group sometimes help, but most of the time I still handle it myself.” (N6)

“I do not dare to deal with an alarm from someone else’s bed. If I turn the alarm off and it affects resuscitation, how could I explain that?” (N3)

“If a patient managed by someone else has an alarm, I do not dare to touch it, because I do not understand that child’s condition.” (N5)

“Alarms are not only for nurses. Doctors and nurses need to manage them together. Whoever sees the alarm should deal with it.” (N8)

Subtheme 2.3. Equipment differences and maintenance management

Nurses reported that PICUs contained many complex devices. Different devices had distinct alarm logics, classification standards and sound frequencies. These differences required nurses to spend considerable additional effort adapting to the alarm characteristics of different devices, increasing the difficulty and cost of alarm management. Older devices reacted slowly, were difficult to operate and were prone to persistent false alarms. This weakened nurses’ trust in alarm systems, forced them to distinguish true alarms from false alarms among numerous signals, and reduced alarm response efficiency.

“New and old devices are used together, and the alarm sounds are all different. Sometimes you really cannot tell which machine is alarming.” (N6)

“Some devices are extremely sensitive. A slight movement triggers an alarm.” (N3)

“The false alarm rate of devices is high, which increases the difficulty of work.” (N2)

“Some old devices keep alarming, and sometimes the displayed information is wrong. They need to be replaced as soon as possible.” (N14)

Subtheme 2.4. Child-oriented technological updating and training needs

Nurses stated that the age range of children in the PICU was wide and baseline vital signs differed substantially across age groups. Existing monitoring devices offered limited modes and could not provide personalised threshold references according to age, condition and other individual characteristics. Children often expressed physical discomfort or psychological anxiety through crying, which not only triggered device false alarms but also intensified noise in the ward, creating major challenges for alarm management. Nurses indicated that identifying the needs behind children’s crying was a current difficulty. Specialised training was needed to improve non-verbal communication, interpretation of children’s behavioural cues and timely identification of needs, thereby reducing non-actionable alarms caused by unmet needs.

“At present there are three different modules, perhaps only divided into infant, child and adult. I think they should be further differentiated according to age and condition.” (N2)

“Children are not simply smaller adults. I hope the system can be closer to children’s needs.” (N1)

“When a child cries, oxygen saturation may decrease and heart rate measurement may be inaccurate, but the machine detects abnormal vital signs and keeps alarming.” (N4)

“Without their parents nearby, some children may have psychological problems. Nurses need to know what the problem is and help solve it; otherwise the child becomes very irritable and noisy, and the alarms keep sounding. That definitely increases the difficulty of work.” (N3)

Theme 3. Macro system: barriers and drivers in policy, systems and culture

Subtheme 3.1. Absent or underdeveloped alarm management systems

Almost all nurses reported a lack of standardised systems for managing alarms in daily work. Current practices mainly depended on informal routines or experience passed down among staff. Nurses also

noted that responsibility for setting alarm limits was unclear. There were no explicit rules on whether physicians or nurses should decide alarm settings. Nurses sometimes had to make non-standard temporary adjustments to alarms, increasing the decision-making risk and psychological pressure associated with alarm management.

“I have not heard of a unified alarm management system in the department.” (N10)

“There are no rules, and no one records anything.” (N8)

“There is no clear process for handling alarms. You can only judge for yourself.” (N5)

“It is handled based on experience. No one says how alarm limits should be set.” (N11)

“Who sets the alarm limits? Who deals with alarms when they sound? No one specifies this. I think doctors should set them, but in reality nurses do this work.” (N10)

“Nurses certainly do not dare to adjust ventilators. Monitor settings are not adjusted by everyone during handover either. No one specifies who should actually do this.” (N3)

Subtheme 3.2. Limited incentives and support policies

Nurses stated that fear of adverse events could motivate them to take alarm handling seriously, but incentives were also important. At present, incentives related to alarm management were lacking. In addition, existing promotion and evaluation systems did not sufficiently recognise nurses’ alarm management competence. Nurses hoped that training and career development platforms focused on alarm management for critical care nurses could be established to provide positive feedback for professional growth.

“The safety warning cases we usually see make me pay more attention to alarm fatigue. I try to reduce the occurrence of alarm fatigue at work.” (N1)

“If there were corresponding rewards, this might stimulate everyone’s enthusiasm.” (N8)

“Rewards are currently hard to obtain. It is mainly punishment. Handling things well is taken for granted; handling them poorly leads to punishment.” (N8)

“Now we are completely required to publish papers, which is only one aspect. Nurses also need recognition, including a recognition process within the hospital.” (N3)

“I think hospitals and the profession should provide a platform for people involved in critical care so that they can feel a sense of excellence and responsibility as they grow and improve. Their progress should be visible as they develop.” (N3)

Subtheme 3.3. The enabling role of a patient-safety-centred healthcare culture

A healthcare culture centred on patient safety gave nurses a strong sense of responsibility and crisis prevention, becoming an intrinsic driver of alarm management. Almost all nurses regarded child safety as their primary principle and remained highly vigilant about alarm signals.

"Being a PICU nurse is a matter of conscience. The child's family is not around, and the primary nurse is responsible for everything. I am a nurse and also a mother, so I have to be responsible for my children." (N10)

"When I hear an alarm, I deal with it because it is my duty, and I am afraid that danger will occur if I do not handle it." (N7)

"If we do not take it seriously, the child may be in life-threatening danger." (N14)

Discussion

Guided by social ecological systems theory, this study analysed the real experiences and influencing factors of alarm fatigue among PICU nurses from micro, mezzo and macro system perspectives. The findings show that alarm fatigue is not the result of a single factor. Rather, it is produced through interactions among multiple systems. Factors across systems are intertwined, making alarm fatigue among PICU nurses complex and persistent.

Focusing on nurses' physical and psychological health to promote dynamic individual adjustment

The findings showed that long-term exposure to high-intensity alarm stimulation was associated with prominent physical and psychological imbalance among PICU nurses, including anxiety, mental fatigue, auditory hallucinations and sleep disturbance. This is consistent with previous research [30]. Persistent alarm stimulation not only weakens nurses' concentration and response efficiency during work but also interferes with recovery after work. Fatigue and desensitisation tendencies may therefore accumulate and form a vicious cycle of alarm fatigue.

Interventions such as yoga, meditation and creative arts therapy have been shown to relieve physical burnout and psychological stress among nurses [31–34]. Studies also indicate that encouraging clinical nurses to engage actively in self-relief may be more beneficial than relying on passive interventions. Increasing nurses' interest in health promotion resources can stimulate their initiative in self-regulation. Resources such as relaxation audio and restorative break areas are low-threshold and convenient and can facilitate nurses' active physical and psychological adjustment [35, 36]. Because nurses' physical and psychological health problems are unlikely to be resolved through a single intervention [37], continuous and dynamic attention is especially important. Routine screening for alarm fatigue among PICU nurses should therefore be established. Personalised physical and psychological health profiles should be developed, nurses' health status should be dynamically monitored, and convenient support resources that match nurses' interests should be provided to interrupt the vicious cycle of alarm fatigue.

Providing paediatric-specific skills training and building an alarm management development platform

The interviews showed that children in PICUs have limited expressive ability, and paediatric-specific behaviours such as crying and movement often trigger large numbers of non-pathological alarms. Recognising and managing these alarms require nurses to have strong soft skills in non-verbal cue interpretation, behavioural observation, psychological soothing and needs identification. Simulation-based training grounded in clinical practice scenarios has been reported to improve nurses' soft skills [38]. However, current training often focuses on hard skills, such as equipment operation, and lacks paediatric-specific training embedded in PICU clinical scenarios. As a result, training may neglect alarm management soft skills and have limited effects on improving nurses' comprehensive alarm management ability.

At the same time, simply increasing training is insufficient. This study found clear differences in alarm fatigue according to nurses' experience, consistent with previous research [30]. Novice nurses may feel anxious and at a loss when facing frequent alarms because they lack experience. Senior nurses, after long-term exposure to alarm stimuli, may develop auditory adaptation, ignore alarms or rely excessively on experiential judgment, affecting the standardisation and safety of alarm handling. Interventions for alarm fatigue should therefore not be uniform. Strategies for novice nurses should rapidly enhance alarm management ability and reduce anxiety arising from unfamiliar work. Strategies for senior nurses should correct habitual thinking and empiricism and address alarm numbness caused by long-term exposure.

Further analysis suggests that the macro system currently lacks a systematic alarm management training and career development platform. This limits nurses' ability to develop competencies gradually according to professional growth patterns and may contribute to inappropriate coping and intensified alarm fatigue at the micro system level. Novice nurses lack standardised development pathways, while senior nurses lack mechanisms that prompt behaviour adjustment. Future work should therefore be grounded in PICU characteristics, deliver comprehensive paediatric alarm management training that integrates soft and hard skills, and build a paediatric-specific talent development platform for alarm management. Senior nurses should be encouraged to play demonstrative and mentoring roles, helping novice nurses improve their skills while also prompting themselves to correct poor habits. Such an approach could build a reserve workforce for paediatric alarm management and support collective growth.

Optimising support systems and providing multidimensional environmental safeguards

The findings showed that insufficient staffing, ineffective teamwork, and inadequate equipment updating and management were important environmental contributors to alarm fatigue among PICU nurses. The interviews indicated that children in PICUs are critically ill, change rapidly, and generate frequent and

complex alarms. Alarm management therefore places high demands on nurses' attention, judgment and emergency response ability. When staffing is inadequate and workload is high, nurses find it difficult to attend to all alarms. This increases safety risks for children and intensifies nurses' physical and psychological exhaustion. Previous research has indicated that reasonable staffing, flexible scheduling and control of continuous working hours can reduce nurse fatigue, improve concentration and decrease nursing adverse events [39]. Managers should therefore allocate nurse-to-patient ratios reasonably according to patient acuity and work intensity, optimise the frequency and length of night shifts, and establish dynamic workload assessment and flexible staffing mechanisms to provide stable workforce support for alarm management.

Effective teamwork is an important safeguard for improving alarm response efficiency. Nurses commonly expressed the need for colleagues to assist when they could not respond to alarms immediately, a view consistent with previous studies [7]. However, unclear responsibility boundaries and limited understanding of the condition of patients assigned to colleagues restricted teamwork. Research has shown that clear role responsibilities, smooth information-sharing channels and effective communication mechanisms can promote teamwork and improve team effectiveness [40]. Managers should improve teamwork models, clarify responsibility allocation, and establish efficient communication and information-sharing mechanisms. Alarm management is not solely a nursing responsibility; it also requires active physician participation and collaboration [41]. Managers should promote interprofessional alarm response mechanisms, strengthen communication between physicians and nurses regarding alarm parameter settings, dynamic assessment of patient conditions and emergency management plans, and support coordinated alarm management across medical and nursing teams to improve response efficiency.

The interviews also showed that declining performance of older devices, imperfect monitoring device design, and difficulties in equipment updating and maintenance were objective factors that reduced nurses' trust in alarms and aggravated alarm fatigue. Current monitoring equipment is often designed around adult physiology and may not match children's physiological characteristics. Uniform thresholds can trigger frequent false alarms. Different brands use different alarm logic and sounds, increasing identification and judgment difficulty and increasing the risk of alarm numbness and neglect. Older devices with low sensitivity and high failure rates further increase alarm interference. Evidence suggests that optimising device algorithms to better reflect children's physiological and behavioural characteristics can improve alarm credibility [42], and strengthening equipment maintenance and renewal can significantly reduce non-actionable alarm rates and relieve nurses' alarm fatigue [43]. Managers should pay attention to the introduction and application of child-specific devices and promote individualised alarm thresholds based on age, weight and clinical condition. They should also establish a full life-cycle management system for departmental equipment, conduct regular maintenance and inspection, and retire old or faulty devices promptly to provide hardware support for reducing non-actionable alarms and alleviating alarm fatigue.

Improving institutional safeguards and providing sustainable incentives and policy support

Institutional safeguards and policy support at the macro level are core conditions for sustaining measures to reduce alarm fatigue among PICU nurses. This study found that alarm limit settings and response processes lacked clear institutional support in clinical practice. Nurses mainly relied on informal routines or personal experience. This lack of systems blurred responsibility boundaries, meaning that nurses did not dare to intervene in alarms for children assigned to others. It also affected teamwork at the mezzo system level and increased individual decision-making risk and psychological pressure at the micro system level.

Standardised systems are an important basis for ensuring the quality of alarm management. Although the American Association of Critical-Care Nurses and the American Heart Association have issued guidance related to alarm management [44, 45], guidelines are recommendations and are not mandatory. Standardised systems can use institutional requirements to ensure that recommendations are implemented in routine practice. At present, China still lacks national or regional institutional promotion and implementation of alarm management guidelines, and a standardised alarm management system has not yet been established. No publicly available clinical alarm management guideline specifically for paediatric populations currently exists. Although the American Association of Critical-Care Nurses practice guideline indicates applicability across the life course from neonates to older adults, it does not provide an independent paediatric alarm management section, and its evidence base is drawn mainly from adult ICUs [44]. Because paediatric monitoring alarms have distinctive features related to individualised thresholds and false alarm rates, directly applying adult-oriented approaches carries potential risks. Future work should accelerate the development of paediatric alarm management guidelines. At the macro-policy level, standardised alarm management systems suited to the Chinese context should be established so that guideline recommendations can be translated into routine clinical practice. This would provide important support for nurses' clinical decision-making, reduce psychological pressure and decision-making risk, and support long-term alleviation of alarm fatigue among PICU nurses.

This study also found that a patient-safety-centred healthcare culture gave nurses a strong sense of responsibility and crisis prevention, serving as the main intrinsic motivation for active alarm management. However, current alarm management policies were perceived as punitive and accountability-oriented, with limited positive feedback. Proactive optimisation of alarm management was regarded as simply expected. Previous research has shown that long-term exposure to punitive environments may lead individuals to adopt risk-avoidance strategies and reduce proactive and creative behaviours [46]. Reasonable incentives can strengthen professional identity, stimulate active participation and promote continuous improvement [47]. Existing policies may rely on nurses' fear of adverse events to encourage attention to alarms, but they are insufficient to stimulate intrinsic motivation for proactive alarm optimisation.

Recognition of nurses' professional competence in alarm management can strengthen self-worth and professional identity. However, in current promotion and evaluation systems, the weight given to critical care nursing management ability is relatively low, and nurses' professional contributions to alarm management lack policy recognition and support. Even when nurses invest substantial effort in alarm management, they may not receive career returns equivalent to research papers or teaching achievements. Over time, this can result in learned helplessness: if optimisation behaviours bring no professional reward while mistakes carry considerable risk, the rational choice is to follow minimum standards and avoid additional effort. This suppresses proactive improvement. At the macro-policy level, incentives and support policies for alarm management should therefore be improved. Indicators related to alarm management and optimisation innovation should be incorporated into performance appraisal and excellence awards. The weight of critical care nursing management ability should be increased in professional title evaluation and promotion. These measures could strengthen critical care nurses' sense of achievement in alarm management, stimulate intrinsic motivation, promote a shift from passive response to proactive management, and provide robust support for the long-term sustainability of alarm fatigue reduction.

Limitations

This study has several limitations. Participants were recruited from four tertiary grade A hospitals in northeast China and Inner Mongolia. The sample was geographically concentrated and included only tertiary hospitals. PICUs in different regions and hospitals of different levels may differ in resource allocation, management systems and workload, limiting transferability of the findings. Future research could include samples from broader regions and hospitals of different levels. In addition, when participants recalled their alarm fatigue experiences, recall bias and social desirability effects may have influenced the objectivity of the findings. Finally, this study included only nurses' perspectives. Future research that includes other stakeholders would help develop a more comprehensive understanding of alarm fatigue among PICU nurses.

Conclusion

Guided by social ecological systems theory, this study explored alarm fatigue among PICU nurses as a complex and persistent problem across micro, mezzo and macro system levels. The findings show that these levels are not isolated but interact with one another. Relying solely on a single measure or an individual department is unlikely to achieve long-term improvement in alarm fatigue. Joint interventions are needed, including dynamic individual adjustment at the micro system level, multidimensional organisational support at the mezzo system level, and institutional, policy and cultural safeguards at the macro system level. The findings not only support the applicability of social ecological systems theory for explaining alarm fatigue in healthcare settings but also provide a theoretical basis and practical reference for developing multilevel integrated interventions and long-term improvement mechanisms.

Abbreviations

PICU	Paediatric Intensive Care Unit
ICU	Intensive Care Unit
COREQ	Consolidated Criteria for Reporting Qualitative Research

Declarations

Acknowledgements

We sincerely thank all the caregivers who participated in this study, as well as the experts who helped design the interview outline.

Authors' contributions

LS and YJX designed the study. LS, YJX, and CXJ performed the research and acquired the data. LS, YJX, HHL and CXJ analysed and interpreted the data. LS, YJX, and CXJ wrote the manuscript. HLX and JY revised the manuscript. HLX supervised the study. JY and YF as co-corresponding authors reviewed the manuscript. All authors read and approved the final manuscript.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data availability

The datasets generated and analysed during the current study are not publicly available due to the confidentiality of participants, but are available from the corresponding authors upon reasonable request.

Ethics approval and consent to participate

This study followed the principles of the Declaration of Helsinki. The study was approved by the Medical Ethics Committee of Shengjing Hospital of China Medical University (No. 2024PS1737K). All participants signed an informed consent form before the start of the study.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests

References

1. Herrera H, Wood D. Battling Alarm Fatigue in the Pediatric Intensive Care Unit. Crit Care Nurs Clin North Am. 2023;35(3):347–55. https://doi.org/10.1016/j.cnc.2023.05.003.
2. Ruppel H, Makeneni S, Rasooly IR, Ferro DF, Bonafide CP. Pediatric Characteristics Associated With Higher Rates of Monitor Alarms. Biomed Instrum Technol. 2023;57(4):171–9. https://doi.org/10.2345/0899-8205-57.4.171.
3. Bonafide CP, Lin R, Zander M, Graham CS, Paine CW, Rock W, et al. Association between exposure to nonactionable physiologic monitor alarms and response time in a children's hospital. J Hosp Med. 2015;10(6):345–51. https://doi.org/10.1002/jhm.2331.
4. Michels EAM, Gilbert S, Koval I, Wekenborg MK. Alarm fatigue in healthcare: a scoping review of definitions, influencing factors, and mitigation strategies. BMC Nurs. 2025;24(1):664. https://doi.org/10.1186/s12912-025-03369-2.
5. Salameh B, Abdallah J, Alkubati SA, ALBashtawy M. Alarm fatigue and perceived stress among critical care nurses in the intensive care units: Palestinian perspectives. BMC Nurs. 2024;23(1):261. https://doi.org/10.1186/s12912-024-01897-x.
6. Clark NA, Kyler KE, Allen GL, Ausmus A, Berg K, Beyer J, et al. Variations in Alarm Burden, Source, and Cause Across Inpatient Units at a Children's Hospital. Hosp Pediatr. 2024;14(8):642–8. https://doi.org/10.1542/hpeds.2023-007604.
7. Shogo A, Shun N, Kentaro F, Kazuki I, Nanako K, Hidehiro M, et al. Sustainability of bundled approaches to alarm fatigue: Lessons from a long-term quality improvement study. J Hosp Med. 2026;21(1):34–41. https://doi.org/10.1002/jhm.70129.
8. Roni C, Geraldine R, Osayed C, Jacqueline C, Ullman Amanda J. Crying wolf, alarm safety and management in paediatrics: A scoping review. J Adv Nurs. 2025;81(11):7348–60. https://doi.org/10.1111/jan.16398.
9. Ting Y, Yangchen H, Yiyao B. Psychological impact and intervention strategies for unaccompanied patients in pediatric intensive care units: a narrative review. Transl Pediatr. 2026;15(1):20. https://doi.org/10.21037/tp-2025-aw-767.
10. Bloomer Melissa J, Butler Ashleigh E, Brooks Laura A, Alysia C, Stephen M, Kristen R, et al. Parents' and nurses' experiences of end-of-life care in intensive care for children: A systematic review. Aust Crit Care. 2025;38(6):101455. https://doi.org/10.1016/j.aucc.2025.101455.
11. Uçak A, Cebeci F, Çatal AT. Nurses' Alarm Fatigue Levels in Adult Intensive Care Units and Their Strategies to Reduce Fatigue: A Convergent Parallel Design. J Clin Nurs. 2025;34(5):1691–703. https://doi.org/10.1111/jocn.17644.
12. Nikola H, Davina B, Raffin BS, Kathryn K. Exploring intensive care unit nurses' decision-making in alarm management: A qualitative study. Heart Lung. 2025;75:117–24.

https://doi.org/10.1016/j.hrtlng.2025.09.013.

13. Hohenwallner A, Ufelmann M, Ellermeyer A, Scholze A, Borgstedt L, Poncette A, et al. Assessment of alarm fatigue among intensive care unit nurses: a cross-sectional study. BMC Nurs. 2025;24(1):1157. https://doi.org/10.1186/s12912-025-03781-8.
14. Ali TM, Alharbi MF. AF among Nurses Working in Neonatal and Paediatric Intensive Care Units: A Cross-Sectional Study. Healthc (Basel). 2024;12(16). https://doi.org/10.3390/healthcare12161574.
15. Xu D, Liu F, Ding X, Ma J, Suo Y, Peng Y, et al. Exploring ICU nurses' response to alarm management and strategies for alleviating alarm fatigue: a meta-synthesis and systematic review. BMC Nurs. 2025;24(1):412. https://doi.org/10.1186/s12912-025-03084-y.
16. Pope C, Mays N. Reaching the parts other methods cannot reach: an introduction to qualitative methods in health and health services research. BMJ. 1995;311(6996):42–5. https://doi.org/10.1136/bmj.311.6996.42.
17. Mays N, Pope C. Qualitative research in health care. Assessing quality in qualitative research. BMJ. 2000;320(7226):50–. https://doi.org/10.1136/bmj.320.7226.50. 2.
18. Shaoru C, Hui Z, Su W, Ruxin J, Huiyi Z, Hongmei Z, et al. Determinants of Medical Equipment Alarm Fatigue in Practicing Nurses: A Systematic Review. SAGE Open Nurs. 2023;9:23779608231207227. https://doi.org/10.1177/23779608231207227.
19. Sowan A. Effective dealing with alarm fatigue in the intensive care unit. Intensive Crit Care Nurs. 2024;80:103559. https://doi.org/10.1016/j.iccn.2023.103559.
20. Abena NB, Abubakari W, Giuliano Karen K. Nursing Perspectives on Alarm Fatigue: An Integrative Review. Nurs Health Sci. 2025;27(4):e70253. https://doi.org/10.1111/nhs.70253.
21. Movahedi A, Sadooghiasl A, Ahmadi F, Vaismoradi M. Smart care for dealing with nurses' alarm fatigue in the intensive care unit. J Nurs Scholarsh. 2023;55(4):825–33. https://doi.org/10.1111/jnu.12870.
22. Neal JW, Neal ZP. Nested or Networked? Future Directions for Ecological Systems Theory. Soc Dev. 2013;22(4):722–37. https://doi.org/10.1111/sode.12018.
23. Ornstein MT, Caruso CC. The Social Ecology of Caregiving: Applying the Social-Ecological Model across the Life Course. Int J Environ Res Public Health. 2024;21(1). https://doi.org/10.3390/ijerph21010119.
24. Doyle L, McCabe C, Keogh B, Brady A, McCann M. An overview of the qualitative descriptive design within nursing research. J Res Nurs. 2020;25(5):443–55. https://doi.org/10.1177/1744987119880234.
25. Willis DG, Sullivan-Bolyai S, Knafl K, Cohen MZ. Distinguishing Features and Similarities Between Descriptive Phenomenological and Qualitative Description Research. West J Nurs Res. 2016;38(9):1185–204. https://doi.org/10.1177/0193945916645499.
26. Lu S, Kuo Y, Hung S, Wu C, Wang C, Chou S, et al. Coping strategies of intensive care units nurses in alarm management: a qualitative research study. BMC Nurs. 2024;23(1):713. https://doi.org/10.1186/s12912-024-02374-1.

27. Hennink M, Kaiser BN. Sample sizes for saturation in qualitative research: A systematic review of empirical tests. Soc Sci Med. 2022;292:114523. https://doi.org/10.1016/j.socscimed.2021.114523.
28. Hsieh H, Shannon SE. Three approaches to qualitative content analysis. Qual Health Res. 2005;15(9):1277–88. https://doi.org/10.1177/1049732305276687.
29. Tong A, Sainsbury P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. Int J Qual Health Care. 2007;19(6):349–57. https://doi.org/10.1093/intqhc/mzm042.
30. Zhu L, Wei S, An Y, Hu W, Xie X. Mechanism, contributing factors, and coping strategies of alarm fatigue in intensive care nursing: a qualitative study. Front Public Health. 2025;13:1654389. https://doi.org/10.3389/fpubh.2025.1654389.
31. Athar J, Sanchari R, Shanker AU, Salina S, Poonam J. Yoga for Burnout in Nurses: A Systematic Review and Meta-analysis of Randomized Controlled Trials. Int J Yoga. 2026;19(1):21–31. https://doi.org/10.4103/ijoy.ijoy_87_25.
32. Arya RG, Srivastava D, Divya BR, Madhu, Bhargav H. A Systematic Review of Yoga Interventions on the Mental Health of Nursing Professionals and Students. Int J Yoga. 2025;18(1):13–26. https://doi.org/10.4103/ijoy.ijoy_195_24.
33. Mantelli RA, Forster J, Reed K, Edelblute A, Henry M, Sinn H, et al. Creative Arts Therapy Reduces Psychological Distress in Nonpatient-Facing Healthcare Workers. Am J Med. 2025;138(4):660. https://doi.org/10.1016/j.amjmed.2024.12.002. 8.e5.
34. Cohen C, Pignata S, Bezak E, Tie M, Childs J. Workplace interventions to improve well-being and reduce burnout for nurses, physicians and allied healthcare professionals: a systematic review. BMJ Open. 2023;13(6):e071203. https://doi.org/10.1136/bmjopen-2022-071203.
35. Nejati A, Shepley M, Rodiek S, Lee C, Varni J. Restorative Design Features for Hospital Staff Break Areas: A Multi-Method Study. HERD. 2016;9(2):16–35. https://doi.org/10.1177/1937586715592632.
36. Kim AJ, Na S, Kim JY, Kim SJ, Kim J. An online supportive music and imagery intervention to promote ICU nurses' stress management: Preliminary study. Heliyon. 2024;10(15):e35117. https://doi.org/10.1016/j.heliyon.2024.e35117.
37. George C, Jaya G, Abubaker E, Ania K, Linda S, Kenneth R, et al. Efficacy of Individual-Level Interventions to Mitigate the Risk for Burnout Among Health Care Professionals: A Systematic Review and Meta-analysis of Randomized Controlled Trials. Ann Intern Med. 2026;179(1):51–66. https://doi.org/10.7326/ANNALS-25-00469.
38. Ma L. Quality adjustment and analysis of human resource prices in China: Based on a hedonic price model. PLoS ONE. 2024;19(4):e0297352. https://doi.org/10.1371/journal.pone.0297352.
39. Lishan H, Jinling D, Xiao S. Injury prevention in fatigue-prone nursing environments: a comprehensive review of strategies centered on work design, human factors engineering, and safety culture. Front Public Health. 2026;14:1792065. https://doi.org/10.3389/fpubh.2026.1792065.
40. Elshami W, Ahmed EM, Akudjedu TN, Abueida AH, Ahmed BM, Abuzaid M, et al. The lived experience of interprofessional collaboration in the neonatal intensive care unit and its impact on workflow,

safety and image quality: A phenomenological study. Radiography (Lond). 2026;32(2):103269. https://doi.org/10.1016/j.radi.2025.103269.

41. Mosch L, Sümer M, Flint AR, Feufel M, Balzer F, Mörike F, et al. Alarm Management in Intensive Care: Qualitative Triangulation Study. JMIR Hum Factors. 2024;11:e55571. https://doi.org/10.2196/55571.
42. Kalden Melissa ACM, Goos Tom G, Nico K, Groenendaal Leo A, Reiss Irwin KM, Van Jasper B, et al. The Physiological Effects of an Adjusted Alarm Architecture on a Neonatal Intensive Care Unit. Acta Paediatr. 2025;114(8):1910–7. https://doi.org/10.1111/apa.70054.
43. Vivienne L, Carol G, Allison R, Kelly Michelle A, Lemuel P. Management of medical device alarms in intensive care units: A scoping review. Aust Crit Care. 2026;39(1):101511. https://doi.org/10.1016/j.aucc.2025.101511.
44. Managing Alarms in Acute Care Across the Life Span. Electrocardiography and Pulse Oximetry. Crit Care Nurse. 2018;38(2):e16–1620. https://doi.org/10.4037/ccn2018468.
45. Sandau Kristin E, Marjorie F, Andrew A, Barsness Gregory W, Kay B, Maria C, et al. Update to Practice Standards for Electrocardiographic Monitoring in Hospital Settings: A Scientific Statement From the American Heart Association. Circulation. 2017;136(19):e273–273344. https://doi.org/10.1161/CIR.0000000000000527.
46. Shen C, Yang J, Hu S. Combined Effect of Abusive Supervision and Abusive Supervision Climate on Employee Creativity: A Moderated Mediation Model. Front Psychol. 2020;11:1175. https://doi.org/10.3389/fpsyg.2020.01175.
47. Hehman MC, Fontenot NM, Ramos CD, Muyco JD, Hayes AE, Meyer RE, et al. Registered Nurses and Meaningful Recognition: Contemporary Preferences of a Diverse Workforce. Am J Crit Care. 2025;34(5):335–44. https://doi.org/10.4037/ajcc2025995.

Figures

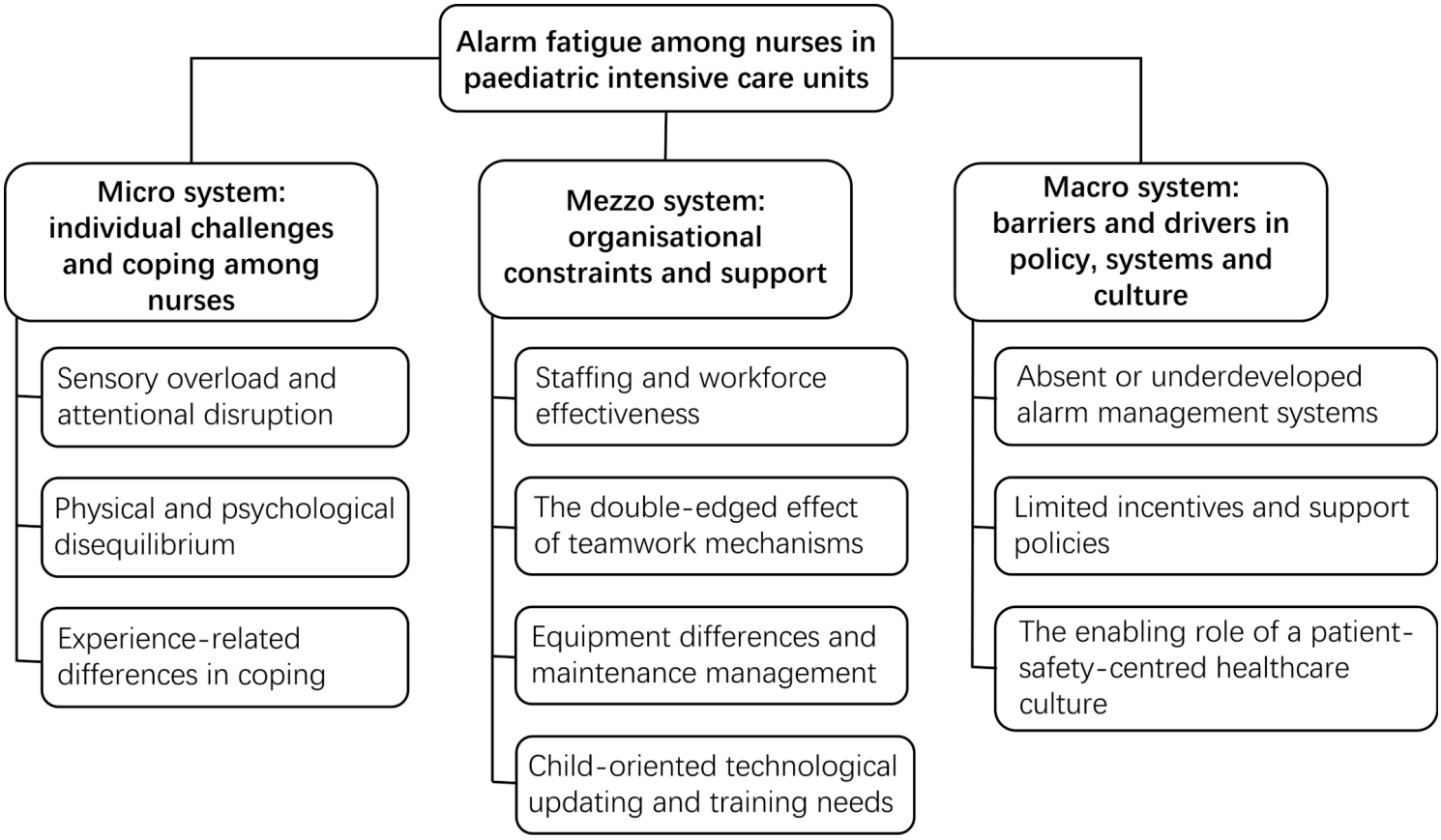


Figure 1

Theme and subthemes