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Smart care for dealing with nurses' alarm fatigue in the intensive care unit

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Smart care for dealing with nurses' alarm fatigue in the intensive care unit

Abstract

Background: Alarm fatigue is a condition in which a person experiences sensory overload or desensitization in exposure to frequent non-actionable alarms. Nurses are the main users of alarms in health care and their behaviors for alarm management influence the occurrence of alarm fatigue.

Objectives: This qualitative research aimed to explore strategies used by nurses in dealing with nurses' alarm fatigue in the intensive care unit (ICU).

Design: A qualitative research was carried out. Eighteen nurses working in ICUs were selected purposefully and were invited to take part in individual semi-structured interviews. Collected data were analyzed using content analysis for developing categories and subcategories.

Setting: Twelve ICUs in ten hospitals in four urban areas of Iran.

Results: The research main category was 'smart care' consisting of two categories of 'technologic actions' and 'non-technologic actions.' Also, six subcategories were developed: 'identifying the cause and taking timely actions', 'personalized alarm settings', 'reducing the number of unnecessary alarms', 'effective teamwork', 'improving the physical environment and ward arrangement', and 'self-calmness'.

Conclusion: Smart care by nurses included a set of active and proactive interventions developed through thinking and reflection, and the use of information, skills and experiences in order to manage exposure to alarm fatigue. Strategies used by nurses to prevent alarm fatigue can reduce physical and psychological burden caused by frequent exposure to alarms in the ICU and consequently can have direct impacts on the quality and safety of nursing care.

Keywords: alarm fatigue, nurse, critical care unit, qualitative study, content analysis, smart care

Clinical Relevance: Nurses in the healthcare process often experience alarm fatigue that is influenced by the cultural-contextual aspect of care and the care environment. Smart care in terms of technologic and non-technologic actions helps with the prevention of alarm fatigue.

Introduction

The frequency of exposure to alarms especially non-actionable ones desensitizes clinical staff to alarms and leads to inadequate responses to vital alarms during the provision of care. This critical problem is known as alarm fatigue and has negative impacts on the quality and safety of care (Cvach, 2012; Horkan, 2014; Sendelbach & Funk, 2013).

The person exposed to alarm fatigue experiences sensory overload or desensitization and do not take required actions. Therefore, the person does not respond properly to real alarms in life threatening conditions. Inappropriate responses consist of delayed or unresponsive actions to alarms, neglect and disabling alarms, or reduction of alarm sounds (Kristensen, Edworthy, & Özcan, 2016). The workload caused by managing multiple alarms during work shifts and related mental stress due to evaluating and prioritizing multiple alarms are the sources of alarm fatigue (Graham & Cvach, 2010).

Alarm fatigue is one of the most important issues affecting patient safety (Solet & Barach, 2012). In addition to related complications and risks for patients, alarm fatigue makes nurses as secondary victims. It is characterized by the feeling of guilt, post-traumatic stress disorder, tendency to leave the job, and frequent turnover (Hravnak et al., 2018). Although alarm fatigue has been well described in the international literature, studies on how nurses can reduce or manage alarm fatigue are insufficient. Some recommendations have been made with regard to the technological reform, interdisciplinary collaboration, and human factors to reduce the negative impacts of alarms on both nurses and patients (Sendelbach & Funk, 2013).

Technological and technical infrastructures are responsible for the occurrence of alarm fatigue. In addition, clinical routines and processes, and workflows have been recognized important. Healthcare staff attitudes, work discipline, clinical and technical competence, collaboration and communication within the intensive care unit (ICU) can all be associated with alarm fatigue. Therefore, a single solution to prevent alarm fatigue cannot be successful (Wilken et al., 2017). A descriptive cross-sectional study involving 62 nurses in cardiac intensive care units in Iran showed that 50% of nurses achieved above the average scores for alarm fatigue. Also, 52% of nurses did not know or were not quite sure about how to prevent alarm fatigue (Sayadi, Seylani, Akbari Sarruei, & Faghih-zadeh, 2019).

Alarm fatigue not only is an individual issue, but also is a socio-occupational problem as well as a multidimensional and possibly psychological phenomenon in the ICU. Development of comprehensive models to guide the development of systematic approaches for the reduction of alarm fatigue is required (Wilken et al., 2017). The first step for the appropriate management of alarm fatigue is to improve our understanding of how nurses can interact with monitoring alarms (Gazarian, Carrier, Cohen, Schram, & Shiromani, 2015). Nurses, as the most important users of clinical alarms need support for the prevention of alarm fatigue. Studies on alarm fatigue has concentrated on the nurses' perceptions of clinical alarms, the role of clinical alarms in patient safety and challenges that users face. However, less attention has been paid to how nurses can deal with alarm fatigue.

Identification of healthcare professionals' perceptions and experiences of this phenomena adds to the existing knowledge, improves the breadth of researchers' vision, reduces ambiguities, and helps with the development of practice and effective solutions (Kristensen, Edworthy, Özcan, & Denham, 2015). Nurses' exposure to alarm fatigue is influenced by the related cultural-care context and environment (Wilken et al., 2017).

The dimensions of alarm fatigue and how to manage and prevent should be discovered from the experiences and perspectives of nurses working in the ICU. It can help identify factors related to the improvement of the quality and safety of nursing care. Therefore, this study aimed to explore strategies used by nurses in dealing with nurses' alarm fatigue in ICUs.

Methods

Design

This qualitative research was conducted using an inductive content analysis approach. In comparison with the quantitative research methods, qualitative research contributes to more in-depth data collection and can provide a cultural-contextual description and interpretation of social phenomena (Holloway & Galvin, 2016). Content analysis as a qualitative descriptive research approach has an important role in the exploration of healthcare phenomena (Vaismoradi & Snelgrove, 2019). It is commonly used for the condensation and abstraction of textual data and help with gaining new insights into various social

phenomena (Vaismoradi, Turunen, & Bondas, 2013). Inductive content analysis is performed where there are no previous studies dealing with a phenomenon or when it is fragmented (Elo & Kyngäs, 2008). So given a lack of studies on how nurses dealt with alarm fatigue, inductive content analysis was performed in this study.

Participants and setting

Participants were 18 nurses consisting of 6 men and 12 women working in 12 ICUs. They were employed in ten different hospitals in four urban areas of Iran and were selected using purposive sampling. Criteria for selecting the participants were: being a nurse with at least 6 months of work experience in the ICU, having the experience of monitoring device and clinical alarms, and willingness to share perspectives. The participants had a bachelor's or master's degree in nursing with an average age of 33 years and an average work experience of 8 years in the ICU. More description of the participants' demographic characteristics has been presented in Table 1.

Data collection

Data were collected through in-depth, semi-structured, individual interviews from September 2020 to June 2021. After obtaining required permissions to conduct the study, the first author visited the nursing offices at the hospitals and requested for gaining access to the list of potential participants. The interviews were scheduled at the time and place convenient to those participants who were willing to take part in this study. However, due to the COVID-19 pandemic and the need for following up related health protocols, 14 interviews were conducted online and in the virtual platforms of Skype, WhatsApp, and via making phone calls.

The flexibility of semi-structured interviews helped with an in-depth exploration of raised issues and reflection on the participants' personal accounts of the research phenomenon. The interview lasted from 50 to 110 minutes with an average of 70 minutes. The interviews began with the following open-ended question: 'What do you do during the work shift in the ICU when you hear alarms?'

Probing and branching questions were also asked to follow the participants' perspectives and collect more data: 'can you explain it more?', 'what do you mean with ...?', 'what happened next?'. Data

saturation was reached at the 15th interview, but three more interviews were conducted to ensure of the comprehensiveness of data collection.

Data analysis

Data analysis was carried out concurrently with the data collection (Elo & Kyngäs, 2008). The interviews were transcribed *verbatim* and were read several times to achieve a general understanding of the participants' statements. Meaning units were determined and relevant codes were assigned. Data abstraction were performed and through the constant comparison of codes based on their similarities and differences, categories and subcategories were developed (Vaismoradi & Snelgrove, 2019; Vaismoradi et al., 2013). All interviews were implemented and analyzed by the first author under the supervision of the research team that had sufficient experiences with qualitative research, nursing management, and ethics.

Ethical considerations

The Research Ethics Committee affiliated with ×× University (decree code: ××) approved the research ethical considerations. The participants were informed about the research's objectives and method, the data collection process, confidentiality and anonymity of personal information, and voluntary nature of participation. They could freely withdraw from the study at any time. They signed the informed consent form before audio-recording the interviews.

Rigor

Criteria suggested by Corbin and Strauss (2015) in terms of credibility, dependability, and transferability were used to ensure rigor (Corbin & Strauss, 2015). For credibility, the first author had prolonged engagement with the data and the participants through collecting additional data and spending more time with the participants during the interviews. Allocation of adequate time to data collection and reading the transcriptions several times added to the depth and the factuality of data. A brief report of the interviews' transcriptions and findings were also provided to some participants and were asked to confirm the researchers' interpretations. The process of data analysis and data abstraction was reviewed and validated by nursing faculty members who were experts in the field of qualitative

research. The participants were selected with a maximum variance in terms of gender, level of education, type of ICU, and work experiences. The whole process of data collection, coding, analysis and development of categories was documented as audit trail and to facilitate transferability of our findings to other caring contexts. The consolidated criteria for reporting qualitative research (COREQ) guideline was used for reporting this study (Tong, Sainsbury, & Craig, 2007) (Supplementary file 1).

Findings

The research main category was ‘smart care’ consisting of two categories of ‘technologic actions’ and ‘non-technologic actions.’ Also, six subcategories were developed: ‘identifying the cause and taking timely actions’, ‘personalized alarm settings’, ‘reducing the number of unnecessary alarms’, ‘effective teamwork’, ‘improving the physical environment and ward arrangement’, and ‘self-calmness.’ (Table 2).

Main category: smart care

It represents a set of effective measures that prevented exposure to alarms and reduced the impact of alarm fatigue on the nurses’ and patients’ well-being in the ICU. These dynamic and conscious activities by the nurses prevented the occurrence or recurrence of alarms and consequently improved tolerance and the individual balance, as well as minimized threats. They were named ‘smart’ because nurses’ activities were proactively planned. The nurses responded in a timely manner to frequent alarms through thinking and reflecting, and using of prior knowledge, skills, and experiences.

Categories

Technological actions

This category represents actions taken by nurses to adjust alarms in medical device in the ICU, reduce the amount of and exposure to alarms, and consequently diminish related psychological burdens in the ICU. This category consisted of the following subcategories: ‘identifying the cause and taking timely actions’, ‘personalized alarm settings’, and ‘reducing the number of unnecessary alarms’.

Identifying the cause and taking timely actions

The nurses assessed alarms at the patient's bedside and identified the real source of alarms and took timely actions for eliminating the cause of the alarm with the consideration of patient safety. They eliminated any patient's vital threat, and permanently eliminated alarms and prevented their recurrence and their own exposure to fatigue.

“How is my reaction to the alarm? I have to check the alarm as soon as possible and eliminate the alarm so that the alarm’s sound does not stimulate our nerves until the end of the work shift.” (P3, master degree (MScN))

The nurses quickly examined the patient in order to identify the source of alarms and reduce related stress.

“Alarm is a warning! It is the patient's tongue that cannot speak. Get up and see what the patient has to do with you! When you do the job, the alarm goes off or goes silent.” (P14, MScN)

They reacted to alarms as fast as they could to prevent the increased workload and related fatigue.

“When I hear alarms from the infusion pump that is used for the administration of a series of medications. I do eliminate that alarm to prevent annoyance. The patient takes sedative medications, and if I reach that alarm lately, the patient wakes up and it can be distressful for the patient. Well, it doubles my work and also fatigue.” (P15, bachelor degree (BScN))

A reason for the occurrence of frequent alarms in the ICU was inappropriate equipment’s calibration. The nurses asked for equipment’s replacement by new ones and therefore reduced the psychological burden of fake alarms.

“There have been many cases where I asked for the replacement of the worn-out device with another one to get rid of fake alarms.” (P5, BScN)

“Sometimes I cannot do anything and I have to change the device.” (P9, MScN)

“If the problem with alarms cannot be resolved, I have to replace the ventilator, and usually the problem with alarms is resolved.” (P13, BScN)

Personalized alarm settings

The nurses adjusted the alarm's threshold based on the patient's clinical condition in order to reduce the occurrence of false alarms. Changing the device sensitivity level and timely detection of critical situations helped reduce clinical complications and probable risks to patients.

“I have to adjust the alarm range based on the patient's condition and diagnosis; for example, a patient with pulmonary fibrosis and acute respiratory distress syndrome needs for various sensitivities to our responses. If I hear alarms, I consider that there is a problem and I take it seriously.” (P4, BScN)

The device alarm's threshold was set specifically for each patient to predict the frequency of alarms' rings and reduce related stress.

“After getting acquainted with the ward routine, I realized that some equipment were set to suit the previous patient's health condition. It was necessary to change the alarm's threshold and later I learned that for every patient, such adjustments must be made. I felt more comfortable and had less stress.” (P10, MScN)

Reducing the number of unnecessary alarms

The nurses took preventive measures based on their experiences to prevent the occurrence of alarms and the related psychological burden. For instance, they prepared medications and administered them before hearing alarms or replaced medication syringes before that the infusion syringe run out of medications.

“If I find that the syringe pump is finished, I prepare the alternative syringe. As soon as the alarm rings, the medicine becomes ready. I always check the syringe pump before it is finished to reduce unnecessary alarms.” (P15, BScN)

Proper experiences of the nurses about alarms facilitated taking timely preventive measures to reduce the occurrence of related stress.

“When I categorize my tasks, I prepare myself for the medication process through the calculations of medications in advance based on my knowledge and experiences. Well, of course, when alarm rings, I can faster eliminate that alarm and reduce my stress level.” (P16, BScN)

The explanation of the nature of alarms to patients reduced the psychological burden on patients and prevented further health problems due to psychological overloads.

“The device rings an alarm, and that flashing light [points to the device] is the source of horror and stress to the patient. My colleague explains it and says: ‘do not be afraid! It is not important.’” (P14, MScN)

“When the patient was admitted, I explained to him that you should not be worried with alarms’ sounds and flashing lights. I stated that ‘I am constantly monitoring you through the camera’. It reduced the patients' stress.” (P17, BScN)

Non-technological actions

This category represents measures that indirectly were taken to reduce the nurses' exposure to alarms or the related psychological burden. This category consisted of the following subcategories: “effective teamwork”, “improving the physical environment and ward arrangement”, and “self-calmness”.

Effective teamwork

The nurses asked for help from other colleagues as the matter of teamwork especially from the more experienced ones to eliminate the cause of clinical alarms.

“If there is a more experienced colleague in the work shift, I refer to him/her and ask what I should do now and what my reaction would be at this moment?” (P7, BScN)

“Many of alarms are really worrying, and the only solution is to get help from other nurses who have more experiences. I request them to help with fixing alarms.” (P8, BScN)

“Once the device rings the alarm, my colleague checks it, and it is a kind of division of labor.”

(P17, BScN)

The lack of teamwork in the ICU was a main factor that reduced nurses' sensitivity to alarms.

“Sometimes my colleague does not rely on my knowledge and expertise. Therefore, I am not allowed to assist with resolving the alarm.” (P1, MScN)

The nurses also appreciated the cooperation of hospital medical equipment engineers in resolving alarms.

“Another thing that was very useful to me was that the medical equipment engineer explained a series of alarms and functions of the device to me. He provided direct support to me.” (P14, MScN)

Improving the physical environment and ward arrangement

The psychological burden of alarms was managed by the nurses through environmental changes. Placing critically ill patients near the nursing station, led to speeding up processing of alarms. They also placed the beds of conscious patients at a distance from the beds of critically ill patients to reduce related noises and the psychological overload caused by alarms in conscious patients.

“Some patients fight with the device, are agitated, and restless, and do not calm down in any way. They need more attention and I bring them in front of the station to check them regularly.”

(P5, BScN)

“There is a conscious patient who has a patient next to him under the ventilator and with frequent alarms. The patient gets really nervous, I have a patient who is crying! I try to move the patient's bed to another place.” (P13, BScN)

To reduce the psychological burden of alarms, the nurses tried to reduce the noise and unnecessary traffic in the ICU.

“I try to reduce noises. I try to reduce the movement of patients' companions and visits.” (P9, MScN)

Self-calmness

The nurses overcame mental and physical fatigue caused by alarms through taking caring measures smoothly before, during, and after the work shift. They took adequate rest and had proper nutrition, drank tea with colleagues during the work shift, exercised, and had more fun after the work shift.

“I try to take sedative teas at home, I rest most of my time at home, I do not do any side chores at all, when I get home I do not have that much ability and energy to play with my child, I try to rest.” (P17, BScN)

“I try to take sedative tea in the ward, I drink tea every few hours, and I get less tired.” (P9, BScN)

“Sometimes I would go out to have more fun because I work in the ICU and am under a lot of pressure.” (P11, MScN)

“What I do to avoid being overwhelmed by alarms is to read books and watch movies and go out with friends.” (P13, BScN)

The nurses with enough rest before the work shift had more energy so that they reacted better to alarms and had less exposure to psychological complications caused by alarm fatigue.

“I come to work with peace and have good nutrition and good energy before coming to my workplace. I always try to come with the maximum energy when I want to come here, whether nutritionally, physically, or mentally.” (P16, BScN)

“When I work at night, I try to rest more before the work shift. In the evening before the work shift I must sleep for an hour or two so that I don't sleep all the night at work.” (P17, BScN)

Discussion

This qualitative study was conducted to understand strategies used by nurses in dealing with alarm fatigue. Smart care aimed to permanently resolve nurses' problems with alarms, prevent alarms, reduce the number of unnecessary alarms, be prepared to face alarms and also increase their ability to overcome fatigue caused by alarms. Two main categories developed in this study were 'technological actions' and 'non-technological actions' in exposure to nurses' alarm fatigue.

Smart care were proactive interventions taken by the nurses through thinking and reflecting and using of knowledge, skills and previous experiences in order to show timely reactions to frequent alarms. Consequently, the amount of alarms and the psychological burden caused by alarms in the ICU were reduced. Nurses, as clinical experts, should use complex intellectual activities to connect their clinical knowledge to specific care contexts in which their knowledge is used (Purkis & Bjornsdottir, 2006). Intelligent care is a comprehensive strategy that recognizes barriers to and facilitators of nursing care. In addition, it helps with the use of predisposing and accelerating forces to turn inhibitors into facilitators (Vahedian-Azimi, Ebadi, Saadat, & Ahmadi, 2015). In a quality improvement project after the implementation of an alarm management bundle, problematic physiologic alarms was decreased, but it had no sensible effect on nurses' alarm fatigue (Seifert, Tola, Thompson, McGugan, & Smallheer, 2021).

In this study, the nurses identified the cause of alarms and took timely and appropriate actions on alarms, tried to take effective care actions to permanently eliminate alarms and reduce the psychological burden of alarms on patients admitted to the ICU. This strategy indicates the feeling of responsibility in nurses, their abilities, skills and knowledge to manage alarms in the ICU (Solet & Barach, 2012). Nurses experience alarm fatigue in the form of sensory overstimulation due to the constant ringing of alarms (Deck, 2016). Prevention of unnecessary alarms is associated with the improvement of patient safety and quality of care (Jubic, 2017). Nurses are the main users of alarms and their alarm management behaviors are key to determine the occurrence of non-actionable alarms and alarm fatigue (Ruppel et al., 2019). Alarm management by nurses consists of the reduction of the number of alarms, prevention of alarm fatigue, the increase of the positive prediction rate of alarms, reduction of the number of non-actionable alarms, and the elimination of alarm fatigue (Winters et al., 2018). The use of training

programs on how to manage alarms can reduce alarm fatigue in the ICU (Bi et al., 2020). However, exposure to non-actionable alarms prolongs nurses' response time to alarms, which can occur due to alarm fatigue (Bonafide et al., 2015).

The participants of our study properly adjusted the alarm range of the device according to the patient's clinical condition in order to reduce false and non-actionable alarms and increase their sensitivity to real alarms. Personalization of the alarm range requires the nurse to have a correct understanding of the physiological and clinical condition of the patient and the therapeutic regimen used to manage the patient's disease. The concept of personalized health care refers to the provision of health care based on the uniqueness of each person to improve the ability to diagnose and predict the disease, provide early intervention, identify new treatment regimens, and address the safety and effectiveness of medications (Spanakis, Patelarou, & Patelarou, 2020). Adjusting alarms based on the real needs of patients ensures the validity of alarms and provides an early warning of possible critical situations (Cvach, 2012). Determining the range of alarms specifically and according to the clinical condition of patients leads to the reduction of the frequency of alarms in the ICU and reduction of alarm fatigue in nurses (Dandoy et al., 2014; Graham & Cvach, 2010). It is believed that the most common reactions by nurses to alarm fatigue are to disable and turn off alarms, and change the threshold of alarms as to reduce the number of alarms without the consideration of their impacts on patient safety. Such passive behaviors can lead to the ignorance of vital alarms and increase of the risk of patients' morbidity and mortality (Nguyen, Davis, Guglielmello, & Stawicki, 2019). Lack of adjustment of the alarm range according to the patient's clinical condition has led to false and non-actionable alarms, which in turn leads to alarm fatigue among nurses (Solet & Barach, 2012).

In our study, the nurses reduced their own exposure to alarm fatigue and prevented the activation of alarms. Nurses relied on their clinical experiences and provided preventive alarm care through anticipating situations leading to alarms and reduction of ringing alarms in the ICU. The nurse's understanding of medications, equipment, and clinical situations led to the provision of these preventive strategies. False alarms are responsible for 83-85% of alarm fatigue cases (Solet & Barach, 2012).

Therefore, reduction of the number of false alarms is the main strategy for the prevention of alarm fatigue (Winters et al., 2018).

According to our research finding, effective teamwork and the use of the experiences of colleagues were mentioned as effective reactions to alarms and prevented alarm fatigue. The participants in this study sought help from colleagues with a higher education level and more experience to react effectively reaction to alarms. Teamwork, the dynamics of the intensive care team, and interpersonal staff-staff and staff-patient communication have been recognized as factors influencing alarm management in the ICU (Solet & Barach, 2012). Improvement of the team performance in the ICU can reduce alarm fatigue (Winters et al., 2018). Unfavorable performances is caused by the lack of experience and unfamiliarity with the work pattern (Warren, 2018).

The nurses highlighted that reduction of the frequency of alarms in the ICU was associated with the improvement of the physical environment and ward arrangement, and reduction of environmental noises. Environmental management and selection of the appropriate environmental design can improve the detection of and reaction to alarms (Elhabashy, 2015). High levels of background noises in the ICU lead to inappropriate responses to alarms (Solet & Barach, 2012). The reduction of stress symptoms in patients and staff in ICUs depend on appropriate voice reduction strategies (Ryherd, Waye, & Ljungkvist, 2008).

Self-calmness helped overcome fatigue caused by alarms in this study. Adequate rest before the work shift helped the nurses gain necessary energy to manage alarms during the work shift. Proper rest and recreation after the work shift helped the nurses manage the psychological burden of alarms. Individual factors such as health level, lack of sleep, and stressful personality of nurses have been recognized to be helpful for managing alarms by nurses (Solet & Barach, 2012).

Limitations

Some participants might have hidden their perspectives and experiences due to the sensitivity of the research phenomenon and the fear of negative consequences of participation in the interviews on their job. However, the researcher ensured the participants about their anonymity and confidentiality of data

during the study process. Further research is needed to understand strategies used by nurses and nurse managers in other healthcare contexts to reduce nurses' exposure to alarm fatigue.

Conclusion

The nature of working in the ICU and constant exposure to alarms increase the risk of alarm fatigue. Therefore, nurses are recognized as the secondary victims of complications caused by alarm fatigue. Smart care was the main strategy of nurses in dealing with alarm fatigue. In comparison with routine organizational strategies for the management of alarm fatigue, smart care emphasizes on human and individual aspects. Our study findings showed that the nurses tried to manage or reduce fatigue caused by alarms in the ICU through a series of proactive interventions consisting of thinking and reflecting, and relying on previous information, skills and experiences. They tried to eliminate alarms permanently by identifying their causes and taking timely actions, personalizing alarm settings, reducing the number of unnecessary alarms, effective teamwork, and physical environment arrangement. Also, they prevented the occurrence of alarms through calming themselves, and controlling related psychological burden caused by frequent and constant exposure to alarms in the ICU.

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Clinical resources

- Agency for Healthcare Research and Quality.
<https://www.ahrq.gov/sites/default/files/wysiwyg/research/findings/making-healthcare-safer/mhs3/alarm-fatigue-1.pdf>

- Anesthesia Patient Safety Foundation. <https://www.apsf.org/article/alarm-fatigue-and-patient-safety/>

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

- Bi, J., Yin, X., Li, H., Gao, R., Zhang, Q., Zhong, T., . . . 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. doi: 10.1111/jocn.15452
- Bonafide, C. P., Lin, R., Zander, M., Graham, C. S., Paine, C. W., Rock, W., . . . Nadkarni, V. M. (2015). Association between exposure to nonactionable physiologic monitor alarms and response time in a children's hospital. *Journal of hospital medicine*, 10(6), 345-351. doi: 10.1002/jhm.2331
- Corbin, J., & Strauss, A. (2015). *Basics of qualitative research: Techniques and procedures for developing grounded theory*. Los Angeles: Sage publications.
- Cvach, M. (2012). Monitor alarm fatigue: an integrative review. *Biomedical instrumentation & technology*, 46(4), 268-277. doi: 10.2345/0899-8205-46.4.268
- Dandoy, C. E., Davies, S. M., Flesch, L., Hayward, M., Koons, C., Coleman, K., . . . Olson, C. (2014). A team-based approach to reducing cardiac monitor alarms. *Pediatrics*, 134(6), e1686-e1694. doi: 10.1542/peds.2014-1162
- Deck, S. (2016). Development of a Policy and Procedure to Decrease Alarm Fatigue.
- Elhabashy, S. (2015). *Clinical Alarms Hazards and Management at Critical Care Settings*: Lulu. com.
- Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing*, 62(1), 107-115. doi: 10.1111/j.1365-2648.2007.04569.x
- Gazarian, P. K., Carrier, N., Cohen, R., Schram, H., & Shiromani, S. (2015). A description of nurses' decision-making in managing electrocardiographic monitor alarms. *Journal of clinical nursing*, 24(1-2), 151-159. doi: 10.1111/jocn.12625
- Graham, K. C., & Cvach, M. (2010). Monitor alarm fatigue: standardizing use of physiological monitors and decreasing nuisance alarms. *American Journal of Critical Care*, 19(1), 28-34. doi: 10.4037/ajcc2010651
- Holloway, I., & Galvin, K. (2016). *Qualitative research in nursing and healthcare*: John Wiley & Sons.
- Horkan, A. M. (2014). Alarm fatigue and patient safety. *Nephrology Nursing Journal*, 41(1), 83-86.
- Hravnak, M., Pellathy, T., Chen, L., Dubrawski, A., Wertz, A., Clermont, G., & Pinsky, M. R. (2018). A call to alarms: Current state and future directions in the battle against alarm fatigue. *Journal of electrocardiology*, 51(6), S44-S48. doi: 10.1016/j.jelectrocard.2018.07.024
- Jubic, K. L. (2017). Strategies for Managing Alarm Fatigue in the PICU Setting. *Pediatric Nursing*, 43(5).
- Kristensen, M. S., Edworthy, J., & Özcan, E. (2016). Alarm fatigue in the ward: An acoustical problem? *SoundEffects-An Interdisciplinary Journal of Sound and Sound Experience*, 6(1), 88-104. doi: 10.7146/se.v6i1.24915
- Kristensen, M. S., Edworthy, J., Özcan, E., & Denham, S. (2015). *Alarm fatigue in the perception of medical soundscapes*. Paper presented at the Proceedings of EuroNoise.
- Nguyen, J., Davis, K., Guglielmello, G., & Stawicki, S. P. (2019). Combating Alarm Fatigue: The Quest for More Accurate and Safer Clinical Monitoring Equipment *Vignettes in Patient Safety-Volume 4*: IntechOpen.
- Purkis, M. E., & Bjornsdottir, K. (2006). Intelligent nursing: accounting for knowledge as action in practice. *Nursing Philosophy*, 7(4), 247-256. doi: 10.1111/j.1466-769X.2006.00283.x
- Ruppel, H., Funk, M., Whittemore, R., Wung, S. F., Bonafide, C. P., & Powell Kennedy, H. (2019). Critical care nurses' clinical reasoning about physiologic monitor alarm customisation: An interpretive descriptive study. *Journal of clinical nursing*, 28(15-16), 3033-3041. doi: 10.1111/jocn.14866
- Ryherd, E. E., Waye, K. P., & Ljungkvist, L. (2008). Characterizing noise and perceived work environment in a neurological intensive care unit. *The Journal of the Acoustical Society of America*, 123(2), 747-756. doi: 10.1121/1.2822661
- Sayadi, L., Seylani, K., Akbari Sarruei, M., & Faghihzadeh, E. (2019). Physiologic monitor alarm status and nurses' alarm fatigue in coronary care units. *Journal of hayat*, 25(3), 342-355.
- 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 and Critical Care Nursing*, 67, 103098. doi: 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. doi: 10.1097/NCL.0b013e3182a903f9
- Solet, J. M., & Barach, P. R. (2012). Managing alarm fatigue in cardiac care. *Progress in Pediatric Cardiology*, 33(1), 85-90. doi: 10.1016/j.ppedcard.2011.12.014
- Spanakis, M., Patelarou, A. E., & Patelarou, E. (2020). Nursing Personnel in the Era of Personalized Healthcare in Clinical Practice. *Journal of Personalized Medicine*, 10(3), 56. doi: 10.3390/jpm10030056
- Tong, A., Sainsbury, P., & Craig, J. (2007). Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *International journal for quality in health care*, 19(6), 349-357. doi: 10.1093/intqhc/mzm042
- Vahedian-Azimi, A., Ebadi, A., Saadat, S., & Ahmadi, F. (2015). Intelligence care: a nursing care strategy in respiratory intensive care unit. *Iranian Red Crescent Medical Journal*, 17(11). doi: 10.5812/ircmj.20551
- Vaismoradi, M., & Snelgrove, S. (2019). *Theme in qualitative content analysis and thematic analysis*. Paper presented at the Forum Qualitative Sozialforschung/Forum: Qualitative Social Research.
- Vaismoradi, M., Turunen, H., & Bondas, T. (2013). Content analysis and thematic analysis: Implications for conducting a qualitative descriptive study. *Nursing & health sciences*, 15(3), 398-405. doi: 10.1111/nhs.12048
- Warren, D. (2018). Decreasing malpractice risk in the emergency department. *Journal of Emergency Nursing*, 44(4), 407-408.
- 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. doi: 10.3233/978-1-61499-808-2-107
- Winters, B. D., Cvach, M. M., Bonafide, C. P., Hu, X., Konkani, A., O'Connor, M. F., . . . McLean, B. (2018). Technological distractions (part 2): a summary of approaches to manage clinical alarms with intent to reduce alarm fatigue. *Critical care medicine*, 46(1), 130-137. doi: 10.1097/CCM.0000000000002803

Table 1. Demographic characteristics of the participants.

characteristics	Number
Age (year)	
24-30	7
30-40	9
>40	2
Work experience in the intensive care unit (ICU) (y)	
<5	5
5-10	5
>10	8
Gender	
Male	6
Female	12
Education level	
Bachelor in nursing	9
Master in nursing	9
Type of ICU	
General ICU	5
Surgical ICU	6
Internal ICU	7

Table 2. The products of data analysis in this study.

Main category	Categories	Subcategory
Smart care	Technologic actions	<ul style="list-style-type: none"> • Identifying the cause and taking timely actions • Personalized alarm settings • Reducing the number of unnecessary alarms
	Non-technologic actions	<ul style="list-style-type: none"> • Effective teamwork • Improving the physical environment and ward arrangement • Self-calmness