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Exploring experiences of alarm response and alarm fatigue among nurses working in the ICU of a tertiary care hospital in Karachi, Pakistan: A qualitative study

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EXPLORING EXPERIENCES OF ALARM RESPONSE AND ALARM FATIGUE AMONG NURSES WORKING IN THE ICU OF A TERTIARY CARE HOSPITAL IN KARACHI, PAKISTAN: A QUALITATIVE STUDY.

By

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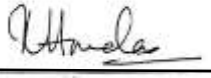

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14th November 202

Dedication

I dedicate this thesis to my beloved family; whose unwavering support and boundless love have ‘been the cornerstone of my academic journey. To my parents**, Mrs. Shehnaz Shamsuddin and Mr. Shamsuddin Qasim Ali**, your sacrifices and encouragement have been the driving force behind my pursuit of knowledge. Your belief in me, even during moments of self-doubt, has propelled me forward. To my spouse, **Mr. Faizal Gillani**, your unwavering support, both emotional and practical, has been my rock. Your belief in my dreams has been the wind beneath my wings, carrying me to this point. To my sibling, **Mr. Shariq Shamsuddin**, your understanding of my bad temper, your patience, and your occasional motivational sessions have made this challenging path feel less daunting. Your presence in my life is a constant source of motivation. To my beloved child **Shazil Faizal**, your understanding of my absence during critical moments and your resilience have inspired me to complete this thesis. I hope it serves as a testament to the importance of education and perseverance.

This thesis is not just my accomplishment; it is a tribute to the love and support of my family. I am eternally grateful for all that you have given me, and I dedicate this work to you with all my heart.

Abstract

Title

Exploring the experiences of alarm response and alarm fatigue amongst nurses working in the intensive care unit of a tertiary care hospital in Karachi. Pakistan: A qualitative study.

Background

Alarm fatigue is a significant concern within the healthcare sector, marked by the excessive exposure of healthcare practitioners to clinical alarms. This prolonged exposure can result in desensitization and delay nurse's responsiveness to vital warnings. The occurrence of inaccurate alarms intensifies desensitization, undermining confidence in alarm systems and potentially leading nurses to ignore alarms. Alarm fatigue is a prevalent issue of worldwide significance, which calls for more investigation to effectively tackle these issues and enhance understanding of alarm systems to get the best possible treatment results. However, there is a lack of study undertaken in Pakistan about the investigation regarding response of intensive care unit (ICU) nurses to clinical alarms and their understanding of alarm fatigue.

Purpose

The objectives of this study are to describe the type and criticality of alarms produced by machines at the patient's bedside and explore the experiences of alarm response and alarm fatigue among nurses working in the ICU of a tertiary care hospital in Karachi, Pakistan.

Methodology

This study used an observational descriptive exploratory methodology to investigate the experiences of alarm response and alarm fatigue among nurses working in the ICU. The research was conducted in an 11-bed intensive care unit, with nurses selected through purposive sampling. Data was collected through observations (camera and documentation)

and interviews, and the findings were analyzed through content analysis. Moreover, synergy model was used as a theoretical framework for this study.

Finding

The study investigated how nurses respond to clinical alerts and their perception of alarm fatigue. The observational findings highlighted a diverse range of alarms and demonstrated variations in nurse responses to these alerts. Additionally, the observations identified discrepancies between the alarms set on monitors and those documented on the flowsheet. The content analysis study identified five key themes: Alarm setting guarantees patient Safety, Alarms response follows standards and patient priority, alarm driven nurse's actions, alarm fatigue exists and is dangerous, alarm fatigue can be combat. Moreover, the study illuminates the consequences of alarm desensitization and explores methods to alleviate alarm fatigue.

Conclusion

The findings of the study offer crucial suggestions for nursing leaders and administrators to enact policies aimed at reducing alarm fatigue among nurses. The recommendations encompass the implementation of procedures aimed at prioritizing alerts according to their level of criticality, the provision of education and training programs focused on the appropriate handling of alarms, and the frequent evaluation of the efficacy of existing alarm systems.

List of Abbreviation / Acronym

CMO: Chief Medical Officer

CNO: Chief Nursing Officer

CRRT: Continuous renal replacement therapy

ECRI: Emergency Care Research Institute

ERC: Ethical Review Committee

FDA: Food and Drug Association

ICU: Intensive Care Unit

TL: Team Leader

Acknowledgments

Firstly, I would like to express my deepest gratitude to Allah the Almighty for giving me the strength to achieve success in all stages of my life, including this significant academic milestone. Your guidance and blessings have been a constant source of inspiration throughout this journey.

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abilities has been a constant source of inspiration, and I am grateful for your presence in my life.

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This thesis is not just my achievement but a collective effort of all these remarkable individuals and divine guidance from Allah. I dedicate this work to all of you with immense gratitude and a heart full of appreciation.

Declaration

I declare that this thesis does not incorporate without acknowledgment of any material previously submitted for a degree or diploma in any university and to the best of my knowledge it does not contain any material previously published or written by another person, except where due reference has been made in the text.

The editorial assistance provided to me has in no way added to the substance of my thesis which is the product of my own research endeavors.

(Signature of Candidate)

14th Nov 2023

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Chapter 1: Introduction

This chapter introduces the current study, "Exploring experiences of alarm response and alarm fatigue among nurses working in the Intensive care unit of a tertiary care hospital in Karachi Pakistan: A Qualitative Study.". The chapter encompasses the background of the study, followed by the study purpose, study question, researcher's reflection, and significance of this study for nursing.

In the past decade, there has been a significant growth in technological advancements in intensive care (jungDe Georgia et al., 2015). As technology advances, critical care equipment like ventilators, bilevel-positive airway pressure machines, cardiac monitors, defibrillators, and continuous renal replacement therapy (CRRT) machines have become increasingly sophisticated and incorporate clinical alarms to enhance patient care and safety. The Joint Commission (2013) defines a clinical alarm as an alert designed to safeguard the individual under care or notify the staff that the individual faces an elevated risk, requiring prompt assistance.

These alarms are seen as a vital component in improving patient safety and reducing life-threatening complications because they alert healthcare professionals about severe situations requiring immediate medical treatment (McFarlane et al., 2018). For instance, bedside cardiac monitors with alarm features are the most effective means of detecting alterations since they notify nurses of abrupt changes in a patient's vital signs via a visual and audible alarm system. However, in cases where the alarms are ignored or responded with a delay, this may lead to an adverse outcome for the patients (T. A. Bach et al., 2018).

Background

Nurses play a critical role in patient care as they monitor patients and respond to critical alarms. Nurses must pay close attention to key alarms to provide effective and high-

quality treatment. Through trials, patient-alerting systems have been proven, to improve patient safety and reduce errors (Ramlaul et al., 2021). However, the publication of the first declaration of alarm-related sentinel incidents by the Emergency Care Research Institute (ECRI), in 1974, drew attention to the potential risks associated with medical alarms and the need for improved alarm management in healthcare settings (Keller Jr, 2012). The specific incident mentioned in the declaration, about a serious patient burn caused by an overlooked alarm signal indicated on a hypothermia machine, highlighted the potential consequences of alarm desensitization and the need for better alarm prioritization and response. Since then, the ECRI has continued to issue reports and recommendations aimed at improving alarm safety and management in healthcare settings (Sendelbach & Funk, 2013).

In 2010 and 2011, the ECRI released a yearly list of the top ten technological risks in healthcare settings, and alarm fatigue ranked second on that list (Purbaugh, 2014). However, in the subsequent years of 2012, 2013, and 2014, alarm fatigue was highlighted on the top of the technology hazard in healthcare, by the ECRI (Purbaugh, 2014). While alarms are intentionally designed to be sensitive to minimize any sentinel events, their high sensitivity results in low specificity, leading to a high rate of false positives. Studies show that 72-99% of the alarms in hospitals are false or clinically inconsequential and do not pose a threat to patients (Sendelbach & Funk, 2013). In addition, nurses receive an average of 700 alarms per patient in a day, with 80% of those alarms being false (Cvach et al., 2015). These high numbers of invalid alarms can lead nurses to be less responsive or to ignore the alarm, resulting in difficulty in recognizing and responding to true emergencies.

Alarm fatigue has been discussed as a risk to patient safety since many decades. Alarm fatigue is a serious phenomenon in healthcare settings, arising from the high number of alarms generated by medical devices (Harris et al., 2017). The repeated, loud noises may exhaust nurses, causing them to deactivate, silence, or disregard the alerts. These

behaviors have been found to have a detrimental influence on patient safety (Ruskin & Hueske-Kraus, 2015). Welch, in 2011, reported that there are at least 40 sources of alarms in any acute clinical environment, and they may occur as frequently as every 30 seconds (Welch, 2011). The excessive number of clinical alarms creates a dissonant and overwhelming sound that can lead to alarm desensitization and inappropriate alarm management practices among nurses (Nix, 2015).

A report by ERCI, in 2012, identified instances where patients were harmed because alarms were silenced or ignored, or because healthcare providers were overwhelmed by the frequency of alarms and missed the critical ones (Horkan, 2014). The Joint Commission (TJC) indicates that between 2009 and 2012, 98 alarm induced sentinel occurrences were reported, of which 80 resulted in fatalities, 13 in irreversible impairment, and 5 patients ended up having prolonged morbidity (Commission, 2013). In response to these concerns, the Joint Commission proposed the National Patient Safety Goals related to alarm system management, in year 2013, to address the issues related to alarm fatigue and to improve patient safety (Commission, 2013). However, recent literature suggests that after so many years of interventions, alarm fatigue is still a persistent problem, which is evident by the study finding that concludes that the ICU nurses received over 2,000 alarms per patient per day, leading to desensitization and increased response time to the alarms (Ceylan et al., 2021).

Nurses respond to an alarm in different ways. A study conducted in 2020 to investigate the nurse’s response to clinical alarms in ICU showed that nurses addressed the alarms 429 times, the responses includes were: turning the alarm off, addressing the patient's complaint, resolving connection and transmission issues, alerting any medical professional of the patient's state, evaluating the patient, and modifying the device configurations and positioning of the patient. The study revealed a high false alarm rate (48%), low nurses'

response rate (46.9%), and long response time (102.81 s), with a significant high rate of alarm silencing. (Ergezen & Kol, 2020). This silencing of alarms and delayed response to an alarm can lead to many sentinel events.

A study by Cvach et al. (2017) found that alarms were identified as a contributing factor in 68% of sentinel events, with a delay in response being the most common cause. According to the Joint Commission, 2013, a sentinel event is an incident that is not anticipated and involves serious psychological or physical injury, or death. The event may lead to permanent harm, severe but temporary harm, or death (Patra & De Jesus, 2023). According to a report by the ECRI Institute (2018), alarm-related sentinel events occurred in 27% of all reported events in healthcare facilities in the United States, with the delayed response being a common contributing factor.

Sentinel occurrences related to ignoring alarm or delaying the response to an alarm alert are underreported, and some researchers believe that the real number of these deaths is higher than what is currently known (Sendelbach & Funk, 2013). Literature shows several cases where patient deaths were attributed to delayed response due to alarm desensitization. One case involved a patient receiving oxygen therapy and dropped oxygen saturation levels triggered an alarm. However, staff members were reportedly desensitized to the alarm due to its falsified frequent activation and did not respond promptly. The patient ultimately died, as the staff failed to respond to the alarm for over an hour (Cvach et al., 2015).

Evidence-based causes for alarm fatigue include: a significantly high rate of false alarms, which can desensitize healthcare providers to critical alarms; alarms that are difficult to hear due to competing noises, which can make it challenging to distinguish between different types of alarms and prioritize responses; trouble determining the severity of alarms, which can lead to confusion and delay in decision-making; and a rise in noise brought on by

an escalation in the number of alerts, which can contribute to a stressful and distracting work environment for healthcare providers. These factors can ultimately lead to a decreased response to alarms and a higher risk of adverse events for patients (Dinis & Rabiais, 2017).

Moreover, one study found that nurses lacked familiarity with alarm customization, which led to inadequate responses to clinical alarms (Movahedi et al., 2023). The study noted that customization of alarm settings is essential to optimize alarm fatigue management and reduce unnecessary alarms. By customizing alarms based on patient acuity, the relevance of the alarm can be increased, while reducing the number of alarms that are not clinically significant. Customizing alarms involves setting specific thresholds for individual patients, which can help decrease the frequency of non-actionable alarms and improve alarm response times for critical alarms (Cvach et al., 2017).

According to the report of the Joint Commission International 2013, alarm fatigue-related incidents are now considered a global issue. As public knowledge of these issues grows, so does recognition and reporting, which aids in determining the scope of the problem and developing strategies to address these issues. The survey emphasized the need for hospitals to develop effective alarm management policies and procedures to reduce the risk of adverse events (ECRI, 2018). To overcome these difficulties and promote alarm deployment in ways that can improve the delivery of quality care, further research is required.

Purpose of the Study

This qualitative exploratory study aimed to investigate and generate a rich description of nurse's experience with alarm response and alarm fatigue.

Study Questions

1. What are the nurse's responses to various clinical alarms in critical care?

2. What are the experiences of critical care nurses regarding alarm fatigue, in the intensive care unit of a tertiary care hospital?

Researcher's Reflection

Alarm fatigue is a global phenomenon that affects both nurses and patients. However, despite extensive research on this topic, no research on alarm fatigue in Pakistan was found during the electronic database search internet search. Moreover, my three-year experience working in the ICU has highlighted several critical alarm system issues. Although policies and procedures exist for clinical alarms, they are often disregarded or disabled, regardless of their reliability. Additionally, nurses may not be familiar with customizing alarms, leading to healthcare providers failing to respond to critical alarms. Therefore, it is crucial to investigate nurses' experiences of alarm response and alarm fatigue and develop effective strategies to alleviate this issue.

Study Significance

This study holds significant importance across several major dimensions. Firstly, this study illuminates the significant challenges that nurses working in high-pressure workplaces encounter while attending to alarms, emphasizing the possibility of overlooked alerts and consequent harm to patients. The purpose of this study is to increase awareness of the critical significance of timely responding to alarms and the necessity of devising the strategies that may efficiently handle alerts while maintaining patient safety.

Moreover, if the study were to uncover a requirement for revisions in alarm management policy, it would facilitate the implementation of essential modifications to the protocol. The proposed modifications would seek to optimize the management of notifications and mitigate the fatigue encountered by critical care nurses, thereby enhancing the quality of patient care and ensuring their well-being.

Also, the study has implications beyond the critical care that could contribute to patient safety in the wider health care system. Despite its immediate effects in critical care, the impact addresses the widespread problem of alert fatigue in an array of healthcare settings. As a result, the research findings greatly enhance the development of effective alarm management and fatigue reduction solutions, enhancing patient safety.

Summary

Alarm response and alarm fatigue can have a significant effect on patient outcomes. Implementing effective strategies, such as reducing the number of non-actionable alarms, customizing alarms to patient-specific conditions, and providing education and training to healthcare providers, can help improve timely nurse's response to the clinical alarms, reduce the burden of alarm fatigue on nurses and improve the overall quality of care. This chapter discussed the background of the study, followed by the study purpose, study question, and significance of this study for nursing.

Chapter Two: Literature Review

This chapter thoroughly reviews the literature on the experiences of nurses with alarm response and alarm fatigue. It is divided into four sections, namely description/explanation of the search strategies employed to gather relevant literature, conceptual definitions of the terms, a review of the empirical literature and theoretical framework related to the topic, and the rationale for the study in Pakistan along with a gap analysis.

Search Strategy

A thorough and methodical literature search was conducted to investigate the experiences of intensive care nurses concerning alarm fatigue and alarm response. The search was performed using various databases, such as PubMed, CINHAL Plus, Science Direct, and Google Scholar, covering the period from January 2013 to August 2023. Most of the articles that were examined were published within the last ten years, but the search also included landmark studies to evaluate the intervention of skin preparedness for electrode placement to reduce alarm fatigue. The search found two articles from 1989 and 1991 to serve the purpose. This approach ensured a comprehensive and diverse collection of literature on the subject matter. Search phrases and keywords used for the review encompassed a range of alarm-related themes, such as “alarm management”, “false alarms”, “alarm fatigue”, “clinical alarms”, “nurse’s role in alarm management”, “nurse’s experience of alarm fatigue” and “nurse attitudes towards alarms”. This comprehensive approach helped to ensure a broad search of the relevant literature on the topic.

A total of 133 articles were found in PubMed after applying mesh words (Alarm management OR Response to Alarms OR False Alarms OR Emergency Responders (Mesh) OR Nurse’s role in Alarm Management OR Critical Care Nurses Response) AND (Fatigue OR Professional Burnout OR Alarm Stress OR Health Personnel) OR Workload OR Patient

Safety), which were further narrowed down to 37, when filters for the previous 10 years, human subjects, full text, and English language format were added. In CINHAL 85 results appeared, which were reduced to 38, while applying the same filters, Furthermore, from Google Scholar, 714 results appeared, which were narrowed down to 600 when filters were applied, and Science Direct yielded 200 articles, which were narrowed down to 100 on applying filters, from which 37 were appropriate to the study.

Lastly, the theoretical framework which will be used for the study was searched. The initial search produced over 10,600 citations using the keyword "Synergy Model." These were condensed to 165 citations by excluding non-nursing material. Following a review, three pertinent articles were found that helped to support the Synergy Model as the theoretical foundation for the stated study. The evaluated literature included a range of items, including papers offering advice for controlling and analyzing alarms, improvement projects, reports from safety organizations, surveys, and reviews of previous work. Observational studies and studies looking at previous alerts were also looked at. The flow diagram below illustrates the process of the literature search.

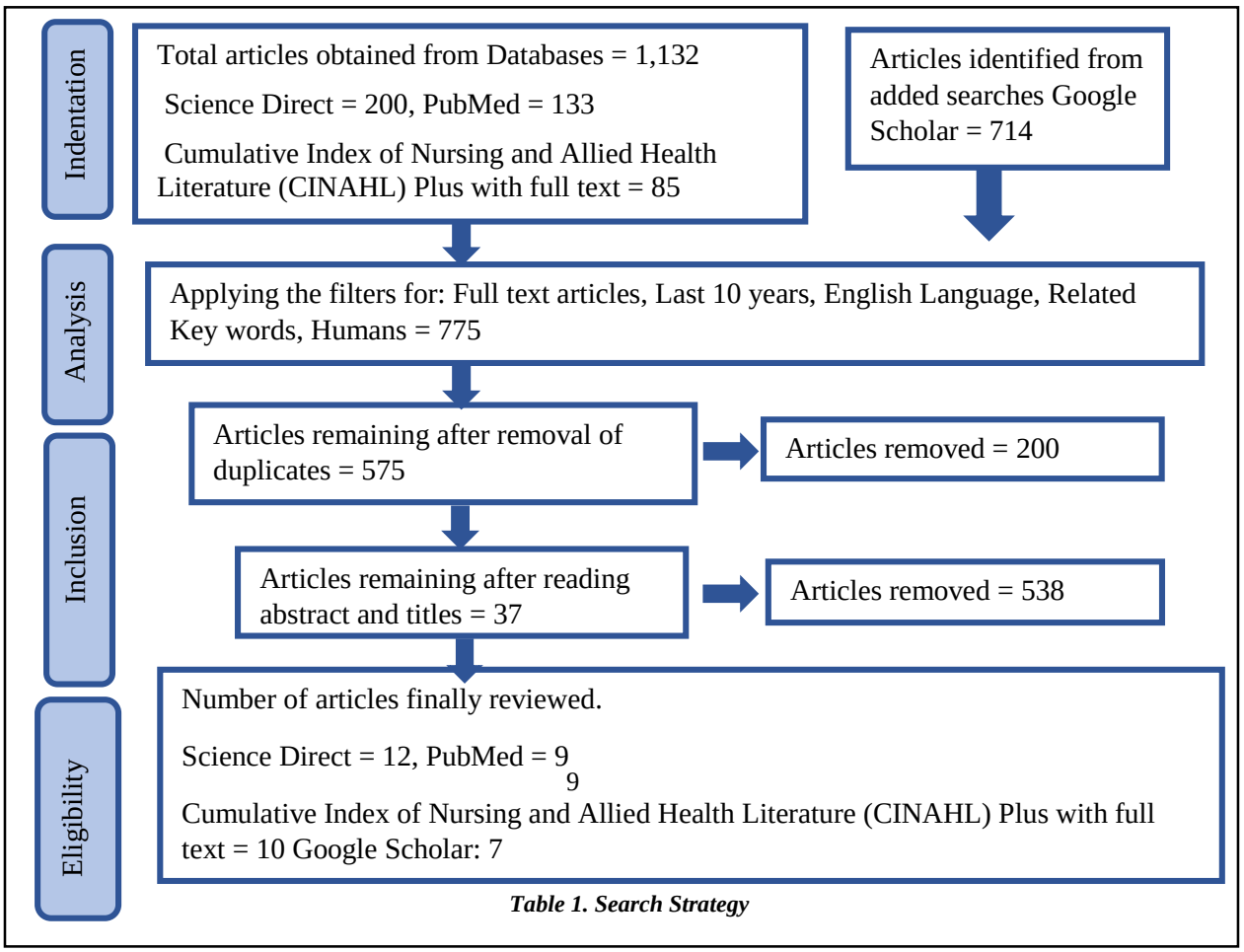


Table 1. Search Strategy

Conceptual Definitions

Alarm fatigue. Alarm fatigue occurs when response of nurses to an alarm is delayed or nonexistent as a result of the nurse's senses becoming desensitized by an excessive number of alarms (Solet & Barach, 2012). This can occur when there is a high frequency or volume of alarms.

Non-critical alarms. In some cases, an alarm may be triggered correctly to indicate a deviation from the expected value, but the value itself may not require any intervention. For instance, a patient may consistently have a normal heart rate of 45 beats per minute, even though the alarm threshold is set at 60 beats per minute. In such cases, the alarm would signal a low value, but it would be within the normal range for the patient, and hence, is not critical for the patients (Lukasewicz & Mattox, 2015).

Level 1 Alarm. A "Life-Threatening Alarm" refers to a critical notification that necessitates an expeditious reaction. Disregarding the sounding of this warning has the potential to result in a catastrophic clinical occurrence (AKUH Policy).

Level II Alarm. A “Potentially Life-Threatening” Alarm refers to an alarm that needs immediate examination and response. The clinical outcome may be influenced by a delay in reaction (AKUH policy).

True alarm. An alarm is considered a valid alarm when it indicates a true patient event or condition that requires healthcare providers' attention or intervention (Korniewicz et al., 2008).

False alarm. The most frequent alarms in healthcare settings are false alarms. These alarms are triggered even though there is no actual indication of a change in the patient's condition (Korniewicz et al., 2008).

Technical Alarm. The alarms initiated by some technical factors that can contribute to invalid alarms and alarm desensitization, such as electronic device interference or equipment malfunctions (Korniewicz et al., 2008).

Alarm response time. The time interval between the initiation of an alarm and the healthcare provider's response to the alarm. Delayed response times may be indicative of alarm fatigue (Korniewicz et al., 2008).

Alarm threshold. The level at which an alarm is triggered by a medical device. It is set to ensure that healthcare providers are alerted to critical events, but it can also contribute to alarm fatigue if set too high or irrespective of the patient's normal parameters (Speich, 2017).

Alarm management strategies. Alarm management strategies refer to a set of practices and techniques aimed at reducing the incidence of alarm fatigue and improving the safety of the patient by optimizing the use of clinical alarms in healthcare settings (Cosper et al., 2017).

Alarms and Alarm Fatigue

A clinical alarm, according to Imhoff and Kuhls is an automated warning that is prompted by a patient's measurement or other state descriptors and indicates a clinically significant deviation from a physiological condition (Imhoff & Kuhls, 2006). While alarms are designed to notify healthcare providers of deviations from the normal rhythm in a monitored environment, the frequent occurrence of monitor alarms can have a detrimental effect on patient outcomes. In any critical care unit, when several thousand alarm signals, nurses get desensitized by the cacophony of alerts, which can reach as many as 942 alarms per day, these signals are believed to be the main cause of alarm-related adverse events, as nurses fail to react to the clinically urgent signals (Commission, 2013).

As alarm fatigue emerges as a serious patient safety concern, therefore, alarm system management has been prioritized in healthcare settings for better outcomes. The Manufacturer and User Facility Device Experience (MAUDE) reporting system of the U.S. Food and Drug Administration (FDA) highlighted 566 complaints of patient fatalities connected to clinical alarms from year 2005 to 2008 (Bach et al., 2018). This is because high number of alarms, has been associated with many unfavorable clinical behaviors by the healthcare provider, for instance, turning off or muting significant alarms, setting inappropriate alarm parameters, and reducing the volume of the alarms to reduce the number of alerts (Bach et al., 2018)

Similarly, a study looked at the reaction times, the clinical significance of alarms, and alarm fatigue in an adult intensive care unit in Colombia. A descriptive, quantitative, observational research design was used in the study, which involved 120 hours of non-participant observation over three months. A total of 5,147 alarms, or 43 alarms per hour, were found. The study showed 37% of alarms received a response within 0 to 60 seconds. Alarm fatigue was visible, though, as 42.5% of alarms were unanswered. There was a statistically significant correlation between the reaction time and the clinical significance of alerts. The study concludes that there is alert fatigue. To reduce alarm fatigue and to improve ICU nurse's response to crucial alarms, improvement measures are required (Andrade-Méndez et al., 2020).

Despite several research and initiatives that have identified unnecessary alarm as a patient safety concern, papers detailing remedies to address this issue are scarce (Bach et al., 2018). This is most likely because alarm incidents are a complicated problem combining human, organizational, and technical aspects. Alarm adverse occurrences can be exacerbated by organizational factors such as a lack of alarm responsibility and difference in the consensus on alarm setting. Human concerns, such as variable response of healthcare

provider to alarms and inconsistent silencing or muting of alarms, and technological difficulties, includes such as varying serious alarm tones and misleading, or false alarms (Bach et al., 2018).

False or Clinically Irrelevant Alarms

The World Health Organization recommended, that the noise level in critical care units should not exceed 35 decibels as it disrupts collaboration and raises the stress levels of the employees (Berglund, 2000). However, these recommendations are often exceeded in practice.. Jung, (2020) demonstrated in their research that the noise level computed in an ICU was between 47-77 dB and that false alarms were considered the most significant causes of these noise-causing sensory overloadA qualitative study to determine which equipment causes the most sensory overload amongst critical care nurses was conducted in North America in 2018 using focus group interviews. Nurses who worked for more than 20 hours per week over the past 6 months were included. The respondents stated that the alarms from cardiac monitors, ventilators, and intravenous pumps were helpful, but the majority of the time contribute to sensory overload. Electronic health record alerts and medication delivery systems alerts/alarms were regarded as being the least beneficial and least likely to cause sensory overload (Wung et al., 2018).

Every day, intensive care nurses are irritated by onerous and false alerts, this erodes the confidence of the nurses on the clinical alarm system and results in a situation where alarms become less alarming for them, and they may not react as they should (Schmid et al., 2013).

According to ECRI (2007), a false alarm arises when the physiological monitoring system identifies a physiologic event that does not really occur (Welch, 2011). To explore why alarms are triggered and how they are responded to, several observational research

methods have been employed. The Healthcare Technology Foundation HTF performed a countrywide online survey of hospital staff, in 2005, to determine the relationship between attitudes and practices regarding clinical alerts. The results showed that 78% of the participants admitted to inadvertently turning off alarm systems. This survey was repeated in 2011, and the results showed no significant improvement. The data indicated that 78% of the respondents still admitted to inappropriately disabling alarms (Foundation, 2011). According to the HTF survey of 2011, 20% or so of hospital employees reported adverse events between 2009 and 2010. The most pressing issue remained the high frequency of nuisance and false alarms, with little progress reported in reducing the hazards associated with alarm systems since the first HTF survey in 2004 (Foundation, 2011).

Similarly, Ergezen and Kol in 2020 conducted a study aimed to explore the types of monitor alarms in an adult intensive care unit (ICU) and how bedside nurses responded to them. The researchers conducted an observational study in a University hospital in Turkey, using nonparticipant observation. Two observers used a semi-structured tool to collect the observations. A sum of 328 hours observations of 13 registered nurses took place between the month of August 2016 and January 2017. During this period, there were 1781 alarms. Blood pressure alerts (37.6%), respiration and oxygen saturation alarms (35.3%), and heart rate and arrhythmia alarms (27.1%) were the three categories into which the alarms were divided. Nearly 46.9% of the alerts that needed a response were attended to by nurses. The responses to the alarms varied. Nurses silenced the alarms, responded to the patient's condition, and take care of the lead attachment problems. The study found that many alarms did not show the actual clinical condition of the patients, indicating a significant high percentage of false alarms. Additionally, as the frequency of false alarms increased, the rate at which nurses responded to these alarms decreased. In conclusion, this study highlights the distribution of alarm types in the ICU and the nurse’s responses to them. It implies the need for better alarm

management strategies to lower the frequency of false alarms and enhance nurse's responsiveness to alarms (Ergezen & Kol, 2020).

Similarly, a prospective, observational study was conducted by Inokuchi et al. in 2013 at the medical ICU of the University of Tokyo Hospital in Tokyo, Japan. This study reviewed alert relevancy in 18 ICU patients and found that while 71% of the alarms were valid, 21.7% of them were technically false. Only 6.4% of all alerts, which comprised of both false and genuine alarms, were clinically appropriate. The authors found that combining physiologic data resulted in a 21.4% reduction in clinically irrelevant alarms (Inokuchi et al., 2013).

Likewise, Drew et al in 2014 focused on electrocardiogram (ECG)-related alarms in observational research in five intensive care units, with a total of 77 beds, at the University of San Francisco. There were 2,558,760 alarms throughout the 31-day research period, with arrhythmia alarms accounting for 1,154,201, parameter alarms for 612,927, and technical alarms for 791,632. An average of 187 alarms were generated per bed per day. The investigation also found that false positives accounted for 88.8% of the 12,671 highlighted arrhythmia alarms. Excessive alerts were brought on by issues like bad alarm settings, protracted atrial fibrillation, and inactive events. (Drew et al., 2014).

Despite being low-priority alarms, technical alerts are frequently regarded as bothersome, and can lead to alarm desensitization (Funk et al., 2014). These are the indications that certain equipment requires maintenance to operate properly. The ECG leads-off warning is an illustration of a technical alarm. However, some technical alarms, though, can have serious repercussions. For instance, if a patient has a lead-off condition, critical events like a potentially fatal arrhythmia may not be detected because the patient is not being monitored.

Nurses' Perceptions of Alarm Fatigue

The nurses perceive alarm fatigue as a significant concern that negatively impacts patient care. However, nurses often feel overwhelmed and frustrated by the constant barrage of alarms; this may result in alarms being inadvertently disabled due to desensitization. Several studies have highlighted the idea that alarms are a serious problem in the healthcare setting and are supported by nurse's unfavorable attitudes towards clinical alarms.

Based on the HTF study from 2004, Clark and David issued an important White Paper in 2006 that looked at the proper use of clinical alerts and reviewed databases of adverse events. The study's findings, as reported in the publication, revealed that the majority of participants believed that too many alarms interfered with patient care and caused caregivers to lose trust in them, which led to sirens being unintentionally disregarded. Similarly, according to Funk, Clark, Bauld, Ott, and Coss, the HTF survey conducted in 2011 showed that respondents believed nuisance alarms frequently impacted patient care. The authors speculated that this could be due to improvements in technology and response to alarms. The authors agreed that clinical alarms remain a cause for concern (Funk et al., 2014).

A descriptive survey approach was undertaken in an Australian Regional Critical Care Unit (CCU) study in 2014 to analyze nurse's views towards clinical alarms. A ten-question survey regarding alarm fatigue and protocols in the intensive care unit was given to forty ICU nurses for this research. The authors classified the replies into five categories: defining nuisance alarms, alarm setting procedures, the act of turning off the alarms, modifying the alarm limits, and notifying colleagues of alarm limit modifications. While the study concentrated on regulating alarm limitations, the results confirmed the premise that too many alerts can lead to desensitization and increased reaction times, which can result in the disabling or silencing of alarms without proper reason. Respondents voiced worries about

vital alerts being ignored and anger about the nursing staff's slow reaction times (Christensen et al., 2014).

Additionally, Honan et al. (Honan et al.) carried out a study depending on what was examined by Funk et al. by looking at free-text comments provided by survey participants in the HTF research of 2011. About 410 nurses, who made up 29% of all respondents in 2011, were examined using qualitative analysis and Krippendorff's analytic approach. Six themes identified were: including desensitization and dissonance, pollution, panic, and pathology, demanding accountability, demanding the authority of nurses, clinical alarm management being necessary but not a panacea, and future optimism. Overall, the comments showed worry about the potential for danger, emphasized particular needs, such as an emphasis on the nurse’s responsibility in the patient care environment, and recommended enhancements for alarm management (Honan et al., 2015).

In the light of above references, health care organizations must foster a culture of ongoing improvement by identifying the negative effects of alarm fatigue and involving nurses in strategies to reduce this burden.

Strategies to Address Alarm Fatigue

AACN Bundle Approach. The Joint Commission's objective is to increase clinical alarm safety; hence, it places a strong emphasis on the value of evidence-based practices and alarm management training. By implementing several interventions to decrease the rate of false and non-critical alarms in the ICU, the AACN proposed an evidence-based bundle to address alarm fatigue in healthcare settings (Winters, 2018). The recommended practices include preparation of the skin for ECG electrodes, routine daily electrode replacement, customization of the alarm levels and settings on ECG monitors, instructions and training on

alarm device use, formation of inter-professional teams to address issues related to alarm, and attaching monitors to only those patients who require alarms (AACN, 2013).

Sendelbach used this bundle interventions in a study at the medical cardiovascular care unit, this study sought to lower the incidence of erroneous electrocardiographic (ECG) alarm signals in adult patients. The researcher put into practice a process for quality improvement that included several interventions, such as getting rid of duplicate alarms, personalizing alarm settings, changing ECG electrodes every day, establishing standards for skin preparation, and utilizing disposable ECG leads. The results indicate that the average daily number of ECG warning signals had significantly decreased. in the cardiovascular care unit. The baseline mean was per day 28.5 alarm signals, and after implementing the bundled approach to alarm management, it decreased to 3.29 alarm signals per day, representing an 88.5% reduction. The study concludes that implementing the bundled approach to manage alarms effectively reduce the frequency of alarm signals effectively in the cardiovascular care unit (Sendelbach et al., 2015).

Similarly, the result of the Quasi-experimental study done by Turmell et al. in 2017, showed that implementing AACN bundle measures, which included personalizing alarms to the patient's state, replacing ECG electrodes every day, standardizing skin preparation, and removing duplicate alarms, reduced alert rates by 30% (Turmell et al., 2017).

In another study, nurses in a surgical intensive care unit (ICU) of a teaching hospital in Northeastern Florida were examined for the utilization of skills they use in management of the alarm and alarm fatigue as a pre post interventional study. A clinical alarms survey was administered to 115 nurses pre and post intervention to assess changes in alarm management perceptions and practices. The results showed that the implementation of the CEASE bundle and training sessions led to improved alarm management competency among the nurses.

There were significant improvements in the perceptions of functionality of alarms, alarm settings, alarm response time, and nurse's adherence to the policy of alarm management. Also, there was a decline in reporting of alarm fatigue. The CEASE bundle was considered to have a positive influence on nursing practice (Bosma & Christopher, 2023).

Electrocardiography Interventions

Alarm fatigue is a common problem in healthcare settings, and electrocardiography (ECG) monitoring is one area where it can be particularly problematic. The Joint Commission recognized false ECG alarms as a considerable technology risk in 2018, posing a risk to patient safety. To address this issue, several interventions have been proposed to reduce alarm fatigue with respect to ECG monitoring. Changing ECG electrodes daily and standardizing skin preparation can also help to improve the quality of ECG signals and decrease the number of false alarms (Drew et al., 2014).

The evaluation of appropriate skin preparation for placement of electrodes was primarily conducted by Medina, Clochesy, and Omery in 1989, and was later revisited in 1991 by Clochesy, Cifani, and Howe. In both studies, it was found that preparing the skin by cleaning it and making it slightly rough helped to reduce artifacts, which are known to cause false alarms (Clochesy et al., 1991).

Prospective descriptive research was carried out by Walsh-Irwin and Jurgens in 2015 to examine the effect of adequate electrode positioning and preparation of the skin on the frequency of ECG alarms. The alert rates were tracked for 24 hours. This was a before and after intervention in the trial, which involved 15 patients at the Veterans Affairs Medical Center, New York. Hair was clipped as necessary, the skin was washed with soap and water, and dried with a washcloth, and electrodes were attached to leads and properly positioned.

The findings revealed a considerable drop in alerts, from 1,341 to 992, or a 44% decrease, in 24 hours (Walsh-Irwin & Jurgens, 2015).

Similarly, a quality improvement strategy was initiated by McGuffin and Ortiz in 2019 aimed at investigating whether daily change of ECG electrodes could reduce the number of nuisance alarms. The study was conducted on an adult inpatient cardiac telemetry unit comprising 36 beds using a quantitative/comparative design. Data was gathered for 14 days—14 days before the intervention (daily electrode changes were not made) and 14 days—during the intervention. A comparison analysis was performed to determine if the number of alarms decreased after implementing daily electrode changes. The results indicated that once daily electrode adjustments were put into place, telemetry alerts significantly decreased. In comparison to pre-intervention levels, post-intervention data revealed a 74.15% drop in alarms. The discussion emphasizes that decreasing bothersome warnings in telemetry equipment can be accomplished by performing daily ECG electrode replacements. By addressing issues related to electrode maintenance, such as skin preparation and placement, healthcare facilities can mitigate false alarms, enhance patient safety, and improve the efficiency of telemetry monitoring (McGuffin & Ortiz, 2019).

Similarly, Speich in 2017, mentioned in his article related to a quality improvement experiment, started in 2011 at The Johns Hopkins Hospital to see if daily electrode replacement on patients may lower the frequency of ECG related technical alerts. The project was carried out in a 25 bed Cardiology Care Unit and a fifteen-bed Medical Progressive Care Unit (MPCU). Each patient's electrodes were changed daily between the hours of 8:00 and 12:00 as part of the intervention, which was in accordance with the policy of The Johns Hopkins Hospital's instructions for skin preparation. For 8 days in each group, the quality improvement project entailed counting the alert rates before and after the intervention as well as defining the type of alarm depending on the level of priority. The intervention group saw a

32% drop in technical alarms in the MPCU and a 56% drop in the CCU by replacing the electrodes on patients daily and following skin preparation protocols (Speich, 2017). Despite being a very small body of research, the findings of this study were convincing enough for AACN to include them as part of the arguments in favor of routine electrode modifications.

On the other hand, at the Cleveland Clinic in Ohio, Albert and colleagues undertook research to see if utilizing disposable EKG lead wires would result in fewer false alarms than using reusable wires. The goal of the study's authors was to find differences between the groups utilizing disposable wires and the ones using reusable wires, not to calculate false alarm rates. The study compared the relative efficacy of the two kinds of wires and it used a prospective, cluster-randomized, controlled, and blinded study. The study involved four inpatient telemetry units, two of which used reusable wires for the initial and subsequent months (control group) and two of which used disposable wires (intervention group), for the next two months, the groups were exchanged. Data were gathered remotely during the course of the study's four-month duration by staff members who were not aware of the participants. Five categories, including real and false alarms, were used to group the alerts. They discovered a substantial difference, with a 29% risk decrease when utilizing disposable wires as opposed to reusable wires. Additionally, it was discovered that there was no difference between disposable and reusable wires in terms of "monitoring (artifact)" and "all false" alert kinds. Yet, there wasn't any discernible difference in the number of genuine emergency alerts and erroneous alerts between the two groups (Albert, 2015). While the study provided some evidence that disposable leads could decrease certain alarm situations, it was not entirely convincing that they could reduce unnecessary alarms in all situations.

Customizing Alarm Settings

Setting alarm parameters based on patient-specific criteria can reduce the number of unnecessary alarms. This demonstrates to have a beneficial impact on patient care, reduce alarm fatigue, enhance patient safety, and improve the overall healthcare environment.

The multidisciplinary team at Boston Medical Center recognized the issue of clinical alarm fatigue and patient anxiety caused by frequent and unnecessary cardiac monitoring alarms on a cardiology unit. To solve this issue, they looked at internal alarm data and monitored the nursing personnel to create better monitoring procedures. Changes were made to the team's alarm-management system, including modifying alarm settings and centralizing patient cardiac data. The modifications included expanding heart rate default limits to accommodate patients with abnormal rates, upgrading certain alarms to crisis alerts for immediate attention, downgrading an advisory alert to a message, and upgrading alarms for atrial fibrillation to audibility. Nurses were also given the ability to adjust alerts to non-audible status for specific patients. This pilot study successfully decreased audible alarms by 89% and reduced the level of the noise from 90 dB to 72 db. No adverse event related to cardiac alarms during the study period was noted, as it was a year prior. Rapid response team activation also decreased by 50%, and patient satisfaction increased. The new alarm system was well-liked by nurses, and 64% of them thought the noise level was appropriate. The authors recommend allowing nurses to modify the default alarms as needed and involving the nurses in the implementation process. Engaging nurses and giving them the ability to customize alarms can lead to successful changes in alarm management (Joy, 2014).

Similarly, in research published in 2016, Brantley et al. sought to determine how pulse oximetry alarm rates were affected by a training session on customizing alarm settings. Critical nurses from the Emory University completed the study, and the findings revealed a statistically significant 39% drop in pulse oximetry alerts following the learning session. The

results of this study signifies how personalizing alarm parameters can decrease the rate of unwanted alarms and lessen alarm fatigue (Brantley et al., 2016).

Another study focused on how intensive care unit (ICU) nurses approach personalizing electrocardiograph (ECG) monitor alerts to lessen alarm fatigue. The study used a convergent mixed methods design and was carried out in three ICUs within a single hospital. Patient's monitor data on the types and number of ECG alarm were gathered, and semi-structured interviews with 27 nurses were undertaken to learn more about the clinical justifications for these practices. According to the findings, 58.7% of the 298 patients had at least one customized alarm. Atrial fibrillation, abnormal heartbeats, and heart rate limitations were the most frequently used custom alarms. The interviews found that nurse's modification practices varied significantly and were driven by things like clinical knowledge, an absence of customization instruction, and bad experiences. The study concluded that alarm customization is a challenging process that needs sufficient assistance to establish secure and reliable procedures. The creation of strategies to enhance alarm customization in ICUs can be guided by the issues identified, such as the disparity in customization practices and the requirement for training and assistance. Proper training of nurses can help address these issues, to improve alarm customizing practices and lessen the consequences of alarm fatigue in ICUs (Ruppel et al., 2018).

Additionally, an evidence-based practicing project was started in 2020 to reduce the incidence of clinically nonactionable alarms in an emergency department. A 36-bed Level I Trauma medical facility in Honolulu, Hawaii was selected for this project. The Iowa Model was chosen as the conceptual foundation. Methods included changing the alarm's default settings and creating a campaign to educate people about alarm safety. A statistically significant drop in the frequency of alarm alerts was found, with an estimated decrease of 14.96. No adverse effects, such as a failure to react quickly enough to a change in the

patient's condition or a delay that led to cardiac arrest, were reported. Multi-modal technique such as training the nurses on alert management, customizing default settings, and emphasizing nurse's accountability were used. This results in the reduced frequency of non-actionable alarms (Fujita & Choi, 2020).

Theoretical Framework

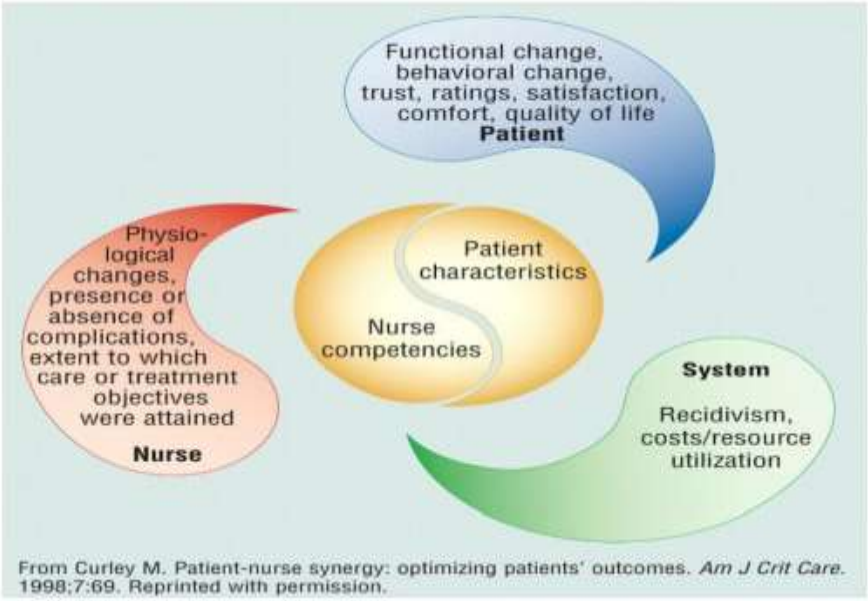
The conceptual framework and methodology for this study were provided by the Synergy Model for Patient Care by the American Association of Critical Care Nursing (Byrum et al., 2020). Eight patient qualities and eight nursing competencies make up this paradigm and when they work together, they improve the outcomes of patients in the care context (Hardin & Kaplow, 2016). Resilience, vulnerability, stability, complexity, resource availability, involvement in care, participation in decision-making, and predictability are the eight patient characteristics. These traits are ranked on a scale of one till five, with one ranking at the lower end and five point being at the higher end (Kaplow & Reed, 2008). The construct includes the family as a group member, who is occasionally subjected to the traits, despite the word "patient" being used in the model. The characteristics of the patient indicate how complicated they are, emphasizing both their potential for health improvement and their susceptibility to further decline from their optimal state of health. The eight nursing skills are clinical judgment, moral advocacy, caring behaviors, collaboration, systems thinking, diversity response, learning facilitation, and clinical research. Similar to patient traits, these competencies also have a grades system based on levels one through five. Based on the patient's levels of acuity, these eight abilities are required to address their demands. For instance, a severely ill patient has more demands than others, necessitating the assistance of a nurse with greater skill (Hardin & Kaplow, 2016). The mobility of both need of patient (a characteristic) and the skill of nurses is a key idea in the Synergy Model. The patient-nurse interaction, however, does not serve as the sole indicator of a nurse's competence. Other

connections, like those between nurses and the healthcare system, are also possible to use (Kaplow & Reed, 2008).

The connections between patient needs, nurse competency, and the hospital system are depicted in Figure 1.

Figure 1

AACN Synergy Model



(Kaplow, 2016)

Alarm weariness focuses on the nurse's incapacity to address the patient's physical, psychological, and spiritual requirements by failing to recognize alarms, thus making the patient even more vulnerable while receiving treatment. Due to their inability to recognize the worrying situation, a nurse is unable to address the patient's needs and is, consequently, not working in synergy. This failure creates an obstacle to a successful relationship since there is a lack of synergy.

Another obstacle to a strong relationship could be nurse attitudes and thoughts about alarms. This study sought to understand nurses' perceptions of alerts and to lessen alarm

fatigue by making patients less vulnerable and enhancing nurses' capacity to exercise clinical judgment. The synergistic relationship between patient needs and nursing skills may be able to be restored as a result (Walsh-Irwin & Jurgens, 2015).

Study Rational and Gap Analysis

The results of the literature review highlight that alarm fatigue is a critical issue in healthcare that impacts both healthcare providers and patients globally. Many qualitative studies have been carried out to explore the experiences of nurses on alarm fatigue and to mitigate the reasons to reduce this fatigue. However, despite extensive research on this phenomenon, there is an absence of local literature related to alarm fatigue. No such study was found in the context of Pakistan that had explored the extent of and/or measures to overcome this phenomenon. This has presented a chance for the researcher to carry out a qualitative investigation in order to examine the phenomenon.

Also, as someone who has worked in the ICU for three years, the researcher has observed the occurrence of alarm fatigue, along with the possible system issues that contribute to this phenomenon. Although policies and procedures exist for clinical alarms, they are often disregarded or disabled, regardless of their reliability. These irregularities in the compliance of responding to alarms being the ultimate indication of alarm fatigue became the motive for the researcher to explore this phenomenon in a Pakistani context and have paved the way for further studies testing some strategies to overcome alarm fatigue.

Summary of the Chapter

In conclusion, false and unimportant alerts affect monitored patients all over the world. A bundled approach that includes numerous measures, such as those involving the ECG and customizing the setting as per patient’s parameter, has been shown to reduce false and unnecessary alarms. The empirical results support that the nurses also assume false

alarms to be a burden, which intentionally or unintentionally makes them ignore the alarm. Moreover, the Synergy Model of Patient Care can be used to manage outcomes and complement the theoretical methodologies of this study.

Although the literature has depicted research regarding the prevailing problem worldwide, no published study on this topic was identified in the Pakistani context. Since alarm fatigue can have a great impact on a patient's health, there was a need to research Pakistan as well. Also, as per the researcher's observation, although hospitals do have certain policies on alarm management, it is still a burning concern. Therefore, this study has provided build insight into what more interventions can be carried out to reduce fatigue.

Chapter 3: Research Methodology

This section presents the research methodology, beginning with the study design, continued by the study setting, study population, sample and sample size, study time frame, recruiting process, eligibility criteria, data collection methods and processes, and data analysis. Furthermore, ethical considerations, study rigor, and the plan for disseminating results are also discussed.

Study Design

This study used observational, descriptive and exploratory techniques to examine the experiences of nurses in the intensive care unit, regarding alarm response and alarm fatigue. Given that the experiences of nurses working in critical care regarding alarm response and alarm fatigue have not been investigated in Pakistan, the study method chosen was considered appropriate for gaining a thorough understanding with regard to the research question. Additionally, due to the study's qualitative design, participants' experiences with alarm response and alarm weariness could be thoroughly examined through this method (Creswell & Poth, 2016).

Study Setting

The study was conducted in a private tertiary care hospital's intensive care unit in Karachi, Pakistan. One of the most well-known medical facilities in Pakistan, the healthcare facility has been accredited by the Joint Commission International (JCIA)

Study Population

The study population consisted of all the nurses working in the intensive care unit and meeting the inclusion criteria in a tertiary care hospital in Karachi, Pakistan.

Sample and Sample Size

The purpose of the study determines the sample strategies (Polit & Beck, 2012). Purposive sampling was the method used to find people who are able to provide thorough explanations on the topic (Grove et al., 2012). The nurses working in an intensive care unit of a tertiary care hospital were a part of the study sample. A total of 12 registered nurses were interviewed for the study, on the basis of data saturation. In a qualitative exploratory study, the data saturation is the point at which no additional data is obtained from the study subjects, and this helps determine the sample size (Polit & Beck, 2012)

Study Duration

The study was carried out between August and September 2023, following the Ethical Review Committee (ERC) of the Aga Khan University approval.

Recruitment of Participants

Below mention is the recruitment process of participants commenced after receiving approval from the Ethical Review Committee (ERC) (Appendix A).

1. The written permission of Chief Medical officer (Appendix B) was taken to initiate the study in the intensive care unit. The intensive care unit is divided into Surgical ICU and Medical ICU.
2. Written permission from the Chief Nursing Officer (Appendix C) of the hospital was taken to conduct the study in the intensive care unit.
3. The Manager and Head nurse were contacted via email to identify potential participants in the unit.
4. An invitation was sent to the prospective participants (Appendix D).
5. A consent letter (Appendix E) for study participation was given to the willing participants.

Eligibility Criteria

For selecting the study's participants, a set of eligibility and exclusion requirements were applied:

Inclusion criteria. Male and female registered nurses having at least one year experience of working at the bedside in the adult Intensive Care Unit of the Aga Khan Hospital Karachi, Pakistan, who can understand and speak English or Urdu language and show a willingness to participate in the study.

Exclusion Criteria. This study excluded registered nurses who work in pediatrics or neonatal intensive care units. Furthermore, registered nurses who are not actively involved in patient care at the bedside, such as nurse managers, head nurses, and nurse instructors, were excluded from the study. Those who refuse to give their consent were excludedfrom the study.

These criteria were designed to guarantee that individuals have adequate exposure to the phenomenon of interest, and restricting the experience to the critical care unit assures participants homogeneity.

Data Collection Method

The data was collected through non participatory observations and semi-structured individual interviews. The first stage was non participatory observations which were done via ICU camera surveillance (Appendix F) and observation of the documents (Appendix G). These observations served as a tool for developing the interview guide in this study. The second phase of data collection was individual, semi-structured, open-ended interviews, exploring nurse’s experiences of alarm fatigue and the reason for desensitization towards the alarm (Appendix H). These interviews were based on observations. The qualitative researchers in the nursing profession collect descriptions using open-ended and semi-

structured approaches, such as interviewing (Creswell & Poth, 2016). The interviews were carried out in Urdu or English, as per the convenience of the participants and was then translated into English if taken in Urdu. According to the literature, researchers should prepare semi-structured interview guides, in order to create a written subject guide, which is a list of topics to be covered with each participant (Polit & Beck, 2019). The data collection method was verbatim and audio recordings.

Pilot testing of the Interview Guide

Prior to the data collection, the interview guide was put through a pilot test on two nurses from the sample, in order to improve the questions, strengthen the probes, and make sure that the guide was comprehensible and usable in the given context. The nurses who participated in the pilot test were excluded from both the sample size calculation and the data analysis conducted for the study.

Data Collection Procedure

Data collection was carried out via observation and semi structured interviews. ICU cameras were reviewed to gather information regarding nurses' response to clinical alarms and documentations were reviewed to observe the alarm setting documented by nurses on flowsheet vs alarms set on the monitor using observation guide. To conduct observation, the researcher reviewed 20 camera recordings of the ICU of three different shifts, to note the alarm sound. Through camera observation, the researcher took detailed field notes of the type, nature, criticality of alarms, way the nurses responded, and the time taken by nurses to respond to those alarms. Also, the researcher observed 15 flowsheets to check for the parameters of the alarms mentioned on the flowsheet and the alarms set on the monitor. These observations of nurses response and documentation guided researcher in helped in developing the interview questions guide. Following the observation, semi-structured interviews were carried out on exploring the experiences of nurses on alarm response and

alarm fatigue, along with the notetaking, in order to capture participants' verbal and non-verbal reactions. Written consent was taken from the interviewees before each interview.

The researcher performed the interviews at a private tertiary care hospital. The interview served as a forum for discussion and introspection about nurses' views in relation to the topic of interest. Each interview continued for 30 to 45 minutes. All interviews were carried out according to the convenience and comfort of the participants, and all of them were audio recorded to aid analysis. In order to guarantee their availability for the interview, the participants were contacted again just before the interview, and once more if needed, to obtain missing or additional information.

Data Analysis Procedure

Data analysis was performed in parallel with data gathering. This aids in detecting any gaps and unclear information, providing the option to seek clarification and fill the gap by getting in touch with the participants once again. During the analysis, the audio data that was acquired during the interviews was controlled and structured. Using Creswell's 2014 method of content analysis, the analysis was done manually, following the steps given below:

1. To preserve participant privacy, each interview received a unique identification number (ID#).
2. As text-based data, all interviews were transcribed and arranged in a word document. The participant identity number, transcription code and categories, topics, and quotations were all included in the data, which was divided into six columns.
3. To determine the important ideas in each transcript, it was read several times and thoughtfully considered.

4. The text in the transcripts that had a similar meaning was grouped together under a single code.

5. To build subcategories and categories, related and similar codes were combined first.

6. Related quotes from the transcripts of the study participants were used to support each group. These were generated by combining similar categories.

7. 7. The themes were generally connected to literature's theoretical framework. To validate the data, it was compared to the body of literature already in existence, and to derive a coherent interpretation. Moreover, the supervisor and committee members consulted throughout the data analysis process.

Ethical Issues

The preparation of a thorough proposal for the Ethical Review Committee (ERC) and approval from the chief medical officer (CMO) and chief nursing officer (CNO) ensured ethical compliance. Throughout the course of the study, the ethical standards of autonomy, anonymity, and secrecy were upheld. Obtaining the participants' informed and written consent served to protect their autonomy. The study's participants were given the assurance that they could leave at any time, without incurring any penalty.

Given the exploratory nature of the study, it did not result in any immediate harm to the participants as a whole. Nevertheless, the potential negative impact caused by the participants' time commitment was carefully taken into account. The interviewees were interviewed based on their own preferences. Furthermore, the study did not provide any form of incentive or financial support to the individuals, except from giving them the chance to contribute to the generation of knowledge and the well-being of patients in the intensive care units. The participants were not subjected to leading questions, and the researcher refrained

from expressing any personal viewpoint during the analysis, in order to mitigate probable biases in the investigation process.

Furthermore, every participant was assigned a unique identification number to protect their anonymity, a practice that was ensured during the full duration of the study. To maintain the privacy of the data, the consent document and physical files of the transcript were securely stored, while all digital versions were stored on a computer with password protection. The data was only accessible to the researcher, committee members, and the supervisor. Furthermore, all the data and audiotapes will be erased in compliance with the institution's policy.

Reflexivity

The researcher's prior professional background, as a nurse in an intensive care unit (ICU), has significantly shaped her inclination towards examining and exploring the diverse facets of alarm weariness. Based on my experience in this professional environment, I have developed a profound commitment to the welfare of patients and staff members. Furthermore, I have cultivated a strong inclination towards comprehending the diverse elements contributing to this phenomenon. Throughout the study, I experienced a profound personal affinity with the intensive care unit (ICU) setting. The aforementioned association catalyzed their subsequent investigation, prompting me to go deeper into the subject matter to comprehend the complex intricacies associated with alarm fatigue.

Study Rigor

The study established trustworthiness by employing Lincoln and Guba's (1985) criteria to enhance the rigor of the investigation. Trustworthiness was determined based on the characteristics of credibility, transferability, conformability, and dependability.

Credibility. Credibility was established through prolonged engagement, which was possible via prolonged observations and by writing down field notes. Member checking, which requires the review of the transcript analysis with the participants, was carried out. In this case a few participants were contacted and asked to confirm the final analyzed data. Data was gathered via multiple sources, i.e., via observations (camera and documents) and interview, and thereby ensures validity of the findings.

Transferability. Transferability was confirmed via a rich description of the data and context in which the study was carried out. The interview format used in the study involved general, open ended guided questions about the study participants' experiences with clinical alarms. This gave the participants the opportunity to speak freely about their experiences, which generated rich detailed descriptions of those experiences.

Conformability and dependability. Conformability and dependability can be achieved by keeping a recordings of individual and group analysis developments, full minutes of group analysis sessions, and coding structure modifications (Nowell et al., 2017 & Moules, 2017). In this research, all data was properly kept and documented to guarantee accurate accounting of the research process. Conformability may also be obtained through reflexivity, which is the researcher's endeavor to reflect on own biases. This can be accomplished through self-reflecting and disclosing the researcher's history and personal sentiments about the subject of the study. Whereby, the result, the reader should be able to determine if bias exists in the analysis of the narrative account.

Dissemination of the Study Findings

The study results will be shared through presentations on quality and patient safety, both outside and within the institution, in order to raise the awareness of alarm fatigue among critical care nurses. Furthermore, the results will be shared with the wider community

through the publication of an article in a journal. This will not only contribute to the existing information in critical care literature, but also provide a basis for future research.

Summary of the Chapter

The chapter provided an overview of the study methodology, encompassing the study design, study setting and population, sample size, and study duration. The section further elucidated the procedure for recruiting individuals, which was thereafter followed by the stipulated eligibility requirements. The chapter systematically expounded on the method of data collecting, starting from obtaining approval from the ethical review committee and culminating in the conduct of comprehensive individual interviews. Ultimately, the chapter delineated the process of analyzing the data, while also addressing the ethical considerations, study rigor, and plan for disseminating the findings.

Study Findings

This chapter constitutes the findings from the study titled "Exploring experiences of alarm response and alarm fatigue among nurses working at the ICU of a tertiary care hospital in Karachi, Pakistan". The findings include observational data from camera surveillance and documents, demographic data of the interviewed nurses, content analysis and conclusion.

The data collection was done in two stages: Stage 1 was observations of nurse's response towards alarm events and the observations of alarm setting documented by nurses on flowsheet vs alarms set on the monitor. These observations were used as a guide for semi structured interviews which was stage 2 of our study. For the convenience of the readers the finding of observations is stated first and that of interview is illustrated next.

Findings from the observation

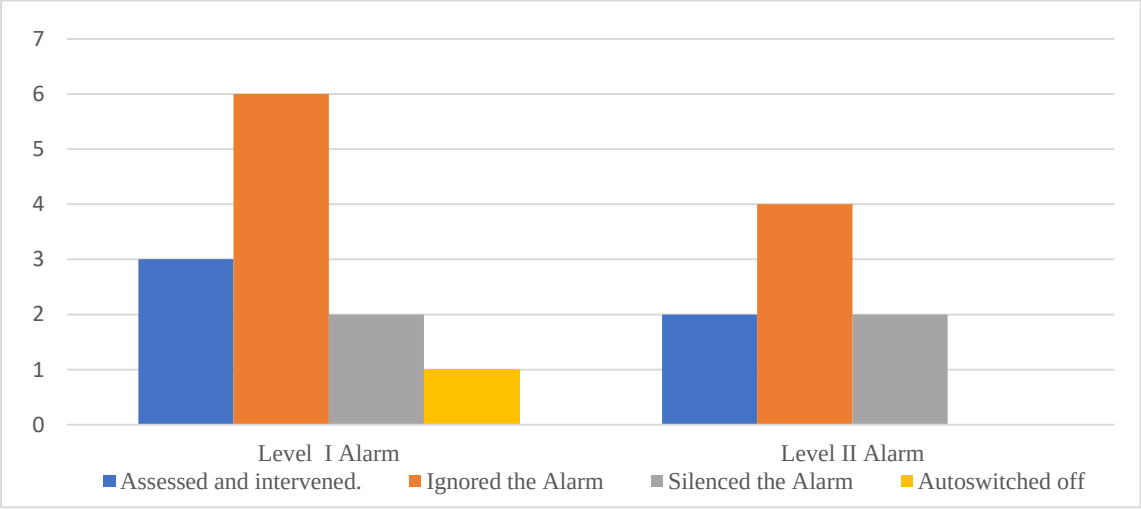
The observations were conducted using camera surveillance and flow sheet observation techniques. The researcher took 20 random observations about how nurses at ICU handled alarms across the morning, evening, and night shifts, for a total of 300 minutes altogether, using an observation guide (Appendix F). During these observations, the researcher observed the nature of alarm (True, False, or Technical Alarm), their type, pertaining to different clinical parameters such as oxygen saturation, blood pressure and heart rate, criticality of alarm (Level I or Level II), the nurse's response to these alarm and time taken for that response (if the alarm was responded). The observation revealed the two criticalities of the alarms: Alarm Level I: Life Threatening Alarm: A crisis alarm that must be responded to immediately. Inattention to this alarm may result in a devastating clinical event. And Alarm Level II: Potentially Life-Threatening Alarm: Warning alarm that requires assessment as soon as possible. Delay in response may have a clinical consequence.

The findings about the criticality of the alarms, from the 300-minute observations of 20 occurrences, revealed a cumulative count of twelve level 1 alarms. Out of these 12 level 1 alarms, the nurses provided responses on just three occasions; six alarms were ignored, two were silenced and one alarm was automatically deactivated due to the absence of a registered nurse at the patient's bedside. The recorded response time for the Level 1 Alarm varied between eight seconds and five minutes. The average response time was recorded as 1.8 minutes.

A cumulative count of eight Level II Alarms were recorded. Within the cohort of level 2 alarms, two nurses evaluated and addressed the patient's condition, while two nurses opted to mute the alarm. The remaining four nurses chose to disregard the alarm and proceeded with their respective duties, which encompassed activities such as documenting or engaging in discourse with their peers. The duration of response time to the Level I Alarm varied between three minutes and ten minutes. The average response time observed in the study was 6.25 minutes. Figure 2 displays how the nurses responded to the alerts.

Figure 2

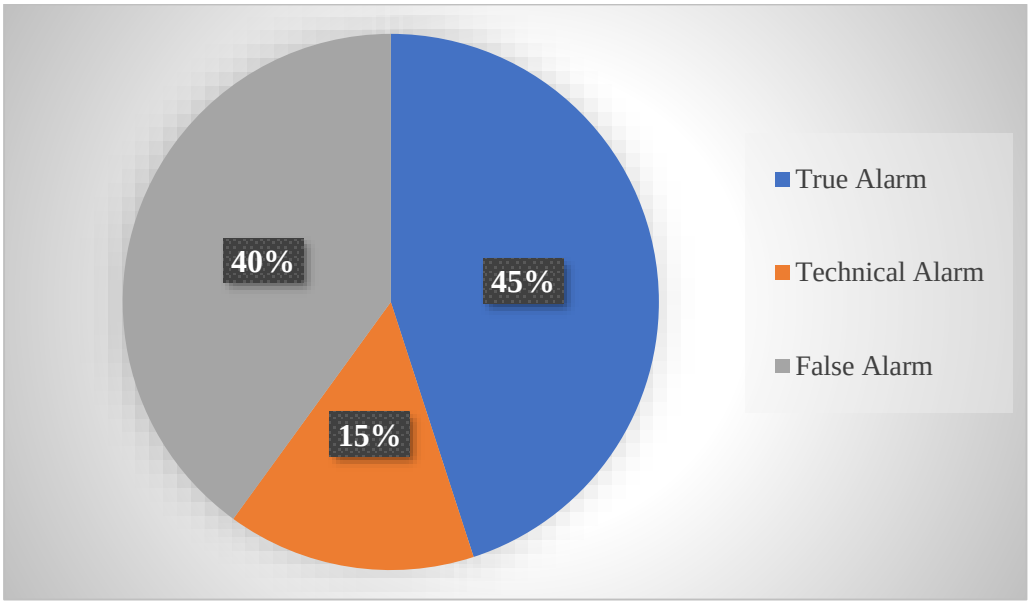
Nurse's Response to Alarms



According to the results, amongst both the criticality of alarms a total of 45 % of alarms (n=9) were true, 40% (n=8) of the alarms in both the Level I and II categories were false and irrelevant, and 15% (n=3) of the alarms were attributed to technical issues, specifically including the detachment or loosening of leads from either the patient or the monitor, as illustrated in Figure 3.

Figure 3

Percentage of Alarms



Flowsheet Data Interpretation

The second phase of the observation was documentation. To uphold patient safety and optimize the delivery of clinical treatment, it is crucial to maintain a vigilant oversight of vital signs and alarms within healthcare environments. Nevertheless, upon meticulous scrutiny of the flowsheet data, some notable findings could be discerned. The subsequent analysis will deconstruct the primary discoveries and their associated ramifications.

The observations revealed a discrepancy between the recommended parameter values indicated on the flowsheet and the implemented settings on the monitoring equipment. These recommended settings were obtain from the AKUH policy of alarm management (Appendix

I). Among the 15 documentations being observed, it was found that 11 alarm settings exhibited inconsistencies in recommended parameter written on the flowsheet vs that of set on the monitor

The analysis of these variations indicates that 13% of the observed disparities were linked to alarms related to heart rate, while 40% were ascribed to alarms connected with blood pressure (including both systolic and diastolic measurements). Additionally, 20% of the differences were found to be associated with alarms triggered by Spo2 levels as mentioned, in Table 2

Table 2:

Flowsheet Data

Actual Setting on the monitor	Recommended setting mentioned in flowsheet
HR: < 60 >120	HR: < 51 > 130
HR: < 51 > 130	HR: < 51 > 130
HR: <60 > 130	HR: < 51 > 130
BP (Systolic): <100 >160 mmhg	BP (Systolic): <90 >160 mmhg
BP (Systolic): <90 >140 mmhg	BP (Systolic): <90 >160 mmhg
BP (Systolic): <80 >170 mmhg	BP (Systolic): <90 >160 mmhg
BP (Systolic): <90 >160 mmhg	BP (Systolic): <90 >160 mmhg
BP (diastolic): < 65 >95	BP (diastolic): < 65 >95
BP (diastolic): < 60 >95	BP (diastolic): < 65 >95
BP (diastolic): < 70 >95	BP (diastolic): < 65 >95
BP (diastolic): < 65 >95	BP (diastolic): < 65 >95
Spo2 : <90 %	Spo2 : <90 %
Spo2 : <92 %	Spo2 : <90 %
Spo2 : <94 %	Spo2 : <90 %
Spo2 : <88 %	Spo2 : <90 %

Experiences of critical care nurses regarding alarm fatigue

These above observations served as a tool for the second stage of our study which was semi structured interviews, below mentioned are the demographic characteristics of the interviewers.

Demographic Characteristics. The demographic data of the twelve participants, including five males and seven females, presented in Table 3 revealed that many of the

interviewees were registered nurses, with a degree of Bachelor of Science in Nursing (BScN) with the years of experience ranging from two years to six years, in medical and/ or surgical intensive care units.

Table 3

Demographic data of the study Participant (n=12)

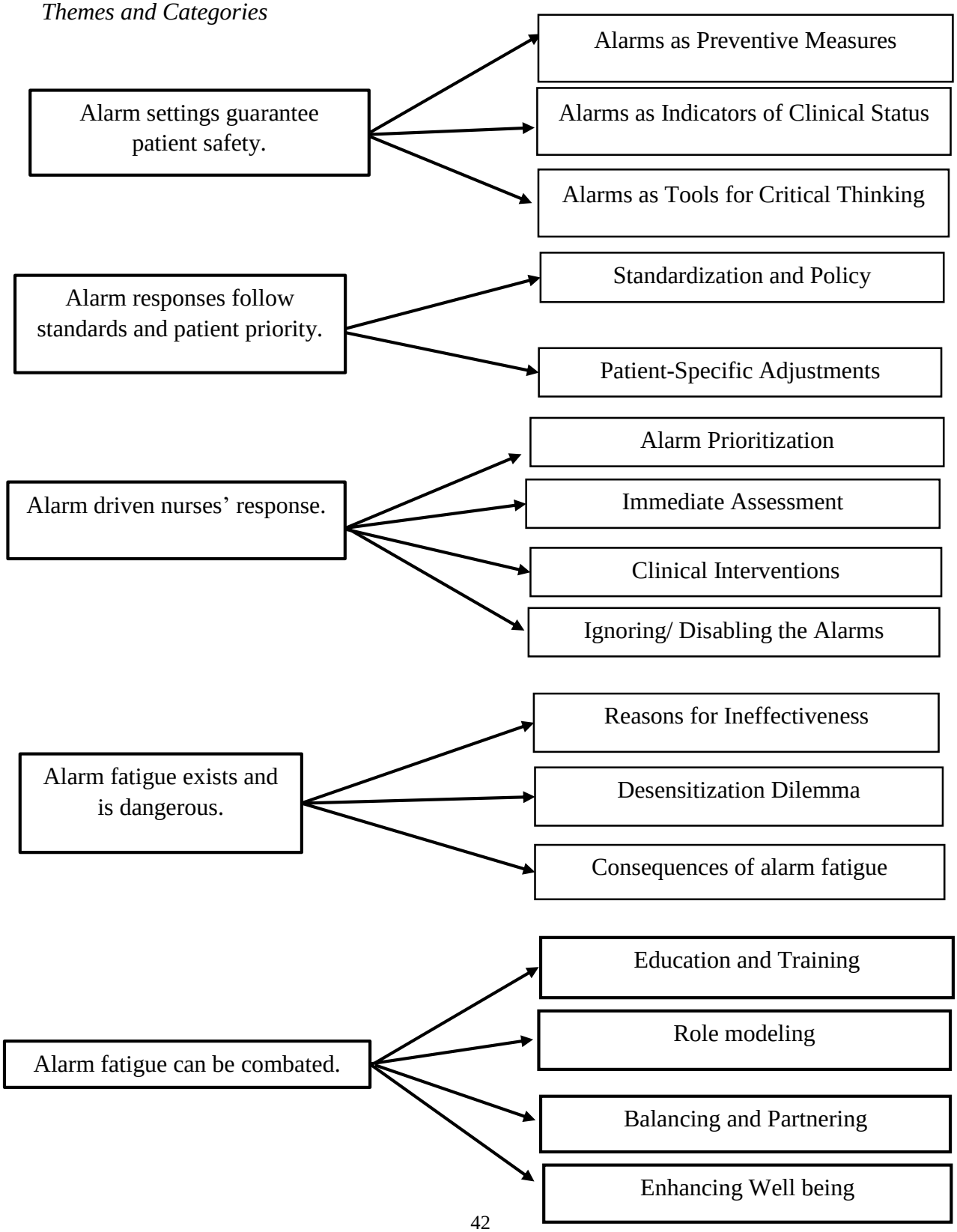
Variables		Frequency	Percentage
Gender	Female	05	41%
	Male	07	58%
Highest Nursing Qualification	Diploma in Nursing	02	16%
	Bachelor of Science in Nursing	10	83%
Designation	Bedside Nurses	12	100%
Years of work experience	More than 1 to less than 3 years	3	25%
	3 years to 5 years	4	33 %
	Above 5 years	5	41%
Area of practice	Medical ICU	5	41 %
	Surgical ICU	7	58 %

The Semi structured interviews provided nurses an opportunity to reflect on and share their experience regarding alarm response and alarm fatigue in the intensive care areas. Moreover, these interviews highlighted the reasons and impact of alarm fatigue on the nurses and patients and identified potential strategies to combat this phenomenon. The interviews were subjected to content analysis, which led to the identification and creation of multiple categories. Subsequently, five major themes emerged from the categories: 1. Alarm settings guarantee patient safety, 2. Alarm responses follow standards and patient priority**,** 3. Alarm

driven nurses' response, 4. Alarm Fatigue exists and is dangerous, 5. Alarm fatigue can be combated. These are presented with respective categories in Figure 4.

Figure 4

Themes and Categories



Theme 1: Alarm settings guarantee patient safety

The theme " Alarm settings guarantee patient safety " exemplifies a significant facet of the nurse's responsibility within a hospital environment. The several categories comprising this theme illuminate the diverse ways in which clinical alarms play a role in enhancing patient safety.

This theme emphasizes the importance of setting clinical alarms on monitors in accordance with the existing policy in order to protect patients from experiencing any harm.

As one nurse explained,

> “Clinical alarms refer to the alarms set on various equipment or devices used for monitoring patients... So, clinical alarms are set on equipment used for patient monitoring and help us ensure the patient's safety and well-being” *(IDI participant 004)c*.

The complex significance of alarms in preserving patient safety can be categorized into Alarm as preventive measures, Alarm as an indicator of clinical status, Alarm as a tool for critical thinking.

By establishing suitable alert settings, healthcare professionals can take proactive measures to avert negative occurrences and rapidly address any alterations in a patient's state. Moreover, alarms play a crucial role in providing nurses with important prompts to thoroughly examine and interpret clinical data, hence, enhancing their ability to make informed decisions and implement appropriate interventions.

Category 1: Alarms as Preventive Measures. All the participants underlined how important clinical alarms are in preventative healthcare. These alarms are not just a system of alerts but offer a proactive approach to patient care. Participants' consistent portrayals position clinical alarms as essential barriers that protect patients from imminent danger and

deterioration. Their focus on alarms presents a comprehensive view, in which clinical alarms are viewed as essential tools that enable preventive medical actions, rather than serving only as technical alerts. One participant succinctly encapsulated the collective sentiment, stating:

> “Clinical alarms serve as early warning systems. They are designed to alert healthcare providers about potential patient safety concerns or any change in a patient's condition. These alarms can prevent adverse incidences and allow for timely intervention, ultimately improving patient outcomes.” (IDI participant 004)

Another participant highlighted clinical alarms as important for alerting healthcare providers before critical events unfold:

> “The alarms alert us before a critical event happens. They provide us with timely notifications, allowing us to take necessary actions, and prevent potential harm to the patient. Additionally, the alarms help us maintain a proactive approach, by constantly monitoring and detecting any potential risks or abnormalities in patient. " (IDI participant 005)

This shows that healthcare providers can act in a timely manner, preventing potential harm to the patients through appropriate attention to the alarms. Emphasizing the mandatory nature and the inherent value of these alarms, another participant mentioned:

> “Clinical alarms make us understand that we need to prevent harm to patients. As per our current policy, we must set clinical alarms on our monitors" (IDI participant 002)

Thus, results of this category demonstrate the significance of clinical alarms in contemporary healthcare, acting as a link between proactive patient monitoring and guaranteeing the best possible outcomes for patients.

Category 2: Indicators of Clinical Status. This category highlights the critical importance of clinical alarms, highlighting their role in the early identification and treatment of clinical anomalies, and establishing them as essential indicators of patient health.

Clinical alarms have become essential instruments that offer instantaneous information about patients' clinical conditions. Participants repeatedly emphasized how important these were for them as they serve as a lighthouse, drawing attention to significant changes or irregularities in a patient's situations. These alarms represent the patient's physiological status and are more than just audible cues, giving healthcare professionals access to critical information that may not be immediately visible. Participants emphasized the alarm's role in drawing attention to crucial changes and deviations.

One nurse lucidly explained the technical aspect, mentioning:

> "Clinical alarms refer to the alarms that are set on monitors based on specific limits related to the vital signs of the patient... These alarms help us monitor and alert us to any deviations from the set limits" (IDI participant 005)

In line with this, another nurse emphasized the anticipatory role of the clinical alarms, explaining:

> "Clinical alarms are set on monitor so that we can identify changes in a patient's condition... The alarms serve as indicators that draw our attention to the fact that something is wrong" (IDI participant 009)

One participant offered a very insightful comparison of clinical alarms with the sensory organs of a healthcare professional, pointing out:

> "They [alarms] are essentially our eyes and ears when we're multitasking" (IDI participant 006)

This sums up the essence of contemporary healthcare settings, which are bustling with activity, where multitasking is the rule rather than the exception. Clinical alarms are essential in these situations because they aid careers remain aware of their patients' needs and changes and enable prompt interventions.

Category 3: Alarms as Tools For Critical Thinking. The participants perceived that clinical alarms played a variety of roles; they have developed from being merely indicators to becoming catalysts that direct and mold critical thinking in clinical settings. The participants provided perspectives that reaffirmed the importance of alarms as indispensable tools for honing cognitive skills and developing decision-making acumen. One nurse aptly expressed:

> "The alarms help us to quickly understand the patient's condition and make quick critical decisions" (IDI participant 003)

This emphasizes the practical importance of clinical alarms in facilitating prompt critical assessment and informed decision-making in healthcare settings. These assertions highlight the transformative function of alarms and how they can simplify cognitive processes, particularly in clinical scenarios where time is of the essence.

This is supported by a participant, who shared:

> "They [alarms] guide our clinical judgments during emergencies and help us prioritize our actions to provide effective care to patients. Without them, it would be much more challenging to quickly identify critical situations and respond appropriately" (IDI participant 007)

Moreover, one participant articulated,

> "Each alarm prompts me to think critically about what's going on with the patient's condition and whether immediate action is needed. It helps me stay proactive and ensures timely interventions to prevent any potential complications." (IDI participant 008)

This perspective emphasizes the cognitive engagement that alarms stimulate, compelling healthcare providers to analyze and respond to each alarm's significance, within the broader context of patient care. As another participant insightfully pointed out:

> "Clinical alarms are indicative of the critical thinking involved in patient care. umm I think critically and then respond according to the situation" (IDI participant 003)

This overarching view underscores that alarms not only serve as tools but also symbolize the staff's commitment to critical thinking and their attentiveness to the evolving condition of the patient. Another participant added:

> "Clinical alarms are the monitoring tool which we use in hospital settings... Through this method, we can treat all humans and our clients from deterioration" (IDI participant 006)

This highlights the usefulness of alarms in protecting patients' health throughout their treatment process.

On the whole, these participant viewpoints highlight how crucial clinical alerts are as tools for encouraging critical thinking and decision-making, highlighting their varied applications in the medical field.

Theme 2: Alarm responses follow standards and patient priority

This theme explores the subtleties of responding to clinical alarms in a medical setting while keeping institutional policies and patient needs in mind. The categories that are a part of this theme examine the various ways that medical professionals engage with and react to these alerts, striking a balance between the necessity of standardization and the dynamic clinical realities that exist in the field.

This theme delves into the intricacies associated with the management of clinical alarms within a medical environment, taking into consideration both institutional protocols

and the requirements of patients. The theme encompasses categories that explore the many approaches and responses of nurses towards these alerts, while considering the need for standardization and the ever-changing clinical circumstances encountered in the field. This theme encompasses two categories namely, Standardization and policy, Patient-specific adjustments.

Standardization and policy initiatives are aimed at maintaining uniform norms and guidelines to safeguard patient well-being and to optimize operational efficiency. The significance of Patient-Specific Adjustments lies in the customization of alert settings to accommodate the specific requirements of individual patients, considering their distinct medical conditions and personal preferences.

Category 1: Standardization and Policy. By delving deeper into the intricacies of alarm responses, this category demonstrates the imperative requirement for healthcare establishments to implement uniform protocols and rules that regulate the utilization and administration of clinical alarms. This category highlights the significance of establishing explicit standards and regulations to facilitate efficient and secure utilization of the alarm systems, thereby reducing the possible hazards linked to alarm fatigue and advancing patient safety.

The participants emphasized the important role of adherence to established protocols and policies when setting up alarms within the intensive care unit (ICU) setting. In this highly specialized environment, clinical alarms are primarily configured based on institutional policies and standardized criteria.

One participant explained:

> "In the ICU, we set alarms on the monitor for the patient. Initially, we set standard alarms according to AKU's policy" (IDI participant 001)

This demonstrates how institutional rules are fundamentally relied upon to guarantee consistent alarm settings that comply with best practices.

Participants also described in detail the specific procedures connected to these policies. As one participant elucidated:

> "The policy states that each alarm has its own predefined value... We mute alarms when we are providing care or performing an intervention on a patient" (IDI participant 004)

This level of specificity highlights the careful approach that healthcare providers take to ensure policy compliance, tailoring alert thresholds to particular clinical scenarios and acknowledging the necessity of temporarily silencing alarms during critical interventions.

Moreover, the participants acknowledged that these alarm policies play a pivotal role in promoting teamwork and shared understanding within the ICU. One nurse aptly articulated:

> "The alarm policies help ensure we are all on the same page and working together towards the common goal of patient safety. It eliminates confusion and allows for effective communication among healthcare professionals, leading to better outcomes for our patients." (IDI participant 008)

This viewpoint emphasizes how policies serve as guiding principles that unite healthcare professionals and promote a common language and practice, which ultimately improves safety and synchronization in the intensive care unit.

Category 2: Patient-Specific Adjustments. The nature of patient care is individualized, even though standardization is essential. This category emphasizes the need for customizing alarm settings and reactions to the unique requirements and circumstances of individual patients. Patient-specific adjustments guarantee that care is both precise and

individualized, whether it's adjusting the heart rate monitor's sensitivity for a patient with arrhythmia or setting particular parameters for a patient.

The results of the current study highlight the need of nurses to periodically adjust alarm settings in order to meet the needs of specific patients. Standardized policies offer a basis for configuring alarms, but real-time clinical evaluations frequently necessitate modifications to guarantee the best possible monitoring of every patient's distinct condition. As expressed by one interviewee:

> “While considering the patient's clinical condition, if there are any changes needed, we make modifications to the alarms in the monitor based on the physician's orders" (IDI participant 001)

This statement emphasizes the dynamic nature of healthcare, where patient-specific considerations may necessitate alterations to alarm settings, highlighting the importance of physician guidance and collaboration.

Another nurse highlighted this practice by stating:

> "In the ICU, alarms are used based on certain predefined criteria. However, some patients have specific conditions... In such cases, we obtain a specific order to modify the acceptable range" (IDI participant 005)

This perspective acknowledges that while standardized criteria serve as a baseline, they may not fully account for the nuances of each patient's medical status, thereby necessitating clear orders to adjust alarm thresholds in response to individualized care needs.

Moreover, another participant underscored the significance of patient-specific adjustments by stating:

> "It's important to adjust the setting of the alarms based on every patient's unique situation. This allows us to minimize unnecessary alarms and ensure that the alarms that do sound are truly indicative of a critical situation. Additionally, by regularly

reviewing and updating alarm settings, we can adapt to any changes in the patient's condition and provide more personalized care". (IDI participant 003)

This captures the essence of the fundamental idea behind patient-centered care, that is, alarm settings should be customized to the unique clinical circumstances of each patient, in order to ensure that monitoring is efficient and meets their needs.

To summarize, in order to maximize patient care and safety in the intricate ICU setting, patient-specific modifications to alarm settings are crucial. This allows for better customization and ensures that alarms are relevant and effective for each individual patient's needs.

Theme 3. Alarm driven nurses' response

Within the realm of healthcare, the concept of "Alarm-Driven Actions of Nurses" highlights the significant influence that clinical alarms exert on a nurse's subsequent actions. The first phase in the process of alarm prioritizing involves nurses promptly evaluating and classifying warnings in order to determine the most crucial ones. This helps them to promptly and efficiently react in order to properly tackle the current circumstances.

The core of their response is in clinical intervention, as nurses utilize the nurses' specialized knowledge and skills to deliver care that is focused on the needs and preferences of the patient. Nonetheless, there exists a nuanced equilibrium is needed when disregarding or deactivating alerts, a judicious choice needs to make when deemed essential, in order to mitigate alarm fatigue and uphold the well-being of patients. This illustrates how nurses, motivated by auditory signals, need to navigate the intricate landscape of healthcare in order to protect and improve the welfare of their patients. This theme includes the categories: Alarm Prioritization, Immediate Assessment, Clinical Interventions, Ignoring/disabling the Alarms.

Category 1: Alarm Prioritization. This category explores the methods and standards that medical professionals employ to determine which alarms require immediate attention. The degree of possible clinical implication, the kind of equipment used, and the patient's general state of health could all have an impact on this. The critical practice of alarm prioritization in the intensive care unit (ICU) setting was revealed in the current research. Participants clarified that some alarms are prioritized over others, especially those connected to life-sustaining equipment like ventilators. The process of prioritization is crucial because it guarantees that patients with life-threatening conditions receive care promptly and urgently. As expressed by one nurse:

> "Ventilator alarms, for instance, are given the highest priority in the ICU because they indicate potential life-threatening situations. These alarms allow us to respond quickly and intervene before the patient's condition worsens." (IDI participant 003)

The statements like this emphasise how important it is to respond quickly to devices that are vital for a patient's survival and how serious some alarms can be, and how crucial these component of patient safety and care is in the intensive care unit.

The significance of proper alarm prioritization is further emphasized by the statement:

> “For an ICU nurse, it's crucial that alarms in the ICU are set properly and that they are able to differentiate between urgent and non-urgent alarms. This allows nurses to respond promptly to critical situations ensuring patient safety and optimal care in the intensive care unit." " (IDI participant 003)

This exemplifies the responsibility and vigilance required of intensive care unit (ICU) workers in ensuring the accurate configuration of alarms, and prioritizing warnings that signal life-threatening conditions. It also underscores the importance of appropriately prioritizing alarms in order to safeguard patient well-being.

In order to optimize patient outcomes, it is imperative for nurses to possess the capacity to promptly and precisely discern the alarms that necessitate urgent care from those that may be attended to at a later time. As underscored by a participant:

> "Not all alarms are of the same urgency, so we prioritize based on the patient's condition. Certain alarms require immediate attention, while others can be attended to a bit later." (IDI participant 005)

The above discussion highlights the intricate process of alarm management within the intensive care unit (ICU), wherein healthcare professionals assess both the patient's state and the clinical environment in order to determine the optimal timeframe for reaction.

Category 2: Immediate Assessment. This category highlights the vital component of patient care, emphasizing the prompt and thorough assessment that ICU nurses perform in the wake of an alarm. To ensure the best possible patient safety and continuity of care, it is imperative that this assessment be done right away, in order to determine the nature and severity of any possible clinical issue and to mobilize the necessary response.

In the intensive care unit (ICU), prompt assessment after an alarm is essential for ensuring patient safety and timely response to evolving clinical conditions. ICU nurses are educated to react quickly to alerts to and determine the cause of them.

As one participant stated,

> "In the ICU, when an alarm goes off, nurses immediately respond to it. They assess the patient, and if they identify any condition indicating patient deterioration, they inform the doctor" (IDI participant 001)

This highlights the significance of prompt assessment in averting potential adverse events and reflects the sense of urgency and responsibility that ICU nurses experience when alarms are set off.

Another participant highlighted the need for a proactive response, stating:

> “They go and check the alarm, not completely ignore it, because they understand that it could be a potential indication of a patient's deteriorating condition. It helps us stay proactive and prevent any adverse events from occurring." (IDI participant 002)

This emphasizes the importance of a thorough and timely evaluation of alarm triggers to ensure that no alarm is ignored without due diligence.

Additionally, another participant noted,

> "Upon hearing an alarm, we immediately conduct a visual check on the patient, ensuring that it's not a false trigger" (IDI participant 005).

The proactive behavior of the participants, in visually evaluating the patient in response to alarms demonstrates their dedication to providing excellent patient care and their vigilant attitude towards prospective alterations in the patient's clinical condition.

These techniques not only serve to reduce unwarranted interventions and disturbances caused by alarms, but also adds to the efficient administration of patient safety within the healthcare setting.

Category 3: Clinical Interventions. This category explores the plethora of medical interventions implemented by the intensive care unit (ICU) in direct reaction to these alerts. Alarm systems serve the purpose of notifying nurses about potential health hazards. These interventions, which encompass a spectrum of activities ranging from basic equipment modifications to intricate medical procedures, are crucial measures conducted promptly to address and alleviate these dangers.

For instance, in the context of ventilation, a participant explained:

> “if the ventilator alarm is also beeping because the patient is desaturating and peak pressures have increased, we immediately perform suctioning, inform the doctor, and adjust the FiO2 and peak pressures accordingly” (IDI participant 001)

This exemplifies the swift and coordinated response required to address complex alarm scenarios, where multiple clinical interventions may be necessary.

Moreover, participants described how alarms serve as guides in the ICU, prompting healthcare providers to take action.

One nurse highlighted this by saying:

> “When confronted with an alarming monitor, we don't just stand by. If a patient's Blood pressure is consistently low, we might adjust their medication or suggest additional interventions to regulate it" (IDI participant 008)

Similarly, another participant revealed that:

> "Alarms are our guides in the ICU. If, for example, a patient's BP drops suddenly and the alarm signals, we might administer fluids or adjust the drug dosage to stabilize it, while also alerting the physician for further orders” (IDI participant 007).

These testimonies demonstrate how clinical alarms empower and direct healthcare providers to provide the best possible patient care in life-threatening situations, capitalizing the mutually beneficial relationship between alarms and interventions.

Category 4: Ignoring/Disabling the Alarms. This category explores the alarming behaviors seen in certain medical professionals who, due to the excessive demands of their jobs, may sometimes ignore or purposefully silence these warning signs. While it's possible that these behaviors occasionally result from the need to attend to another urgent matter, the trend exposes potential training gaps, particularly among junior staff, and emphasizes how crucial it is to respond to alarms consistently and effectively in order to ensure patient safety.

The interviews conducted with participants have shed light on a worrisome pattern in the management of clinical alarms within the high-pressure setting of the Intensive Care Unit (ICU). A participant provided a description of the ICU environment, expressing the sense of being overwhelmed stated that:

"In the hustle and bustle of the ICU, I've noticed occasions when alarms are momentarily ignored or even muted to focus on another task" (IDI participant 006)

This observation highlights the difficulties faced by healthcare professionals in juggling multiple tasks and alarms at once.

The concern is further supported by the sentiment shared by another participant, who noted that although nurses understand the significance of these alerts, there are situations in which alarms are purposefully turned off or even disregarded.

She said,

"Yes, often what happens is that junior nurses, such as intern nurses who have less experience, sometimes tend to neglect alarms" (IDI participant 005)

This phenomenon underscores the notion that the disregard observed might be ascribed to their limited exposure to diverse alarm sounds and their accompanying interpretations. Highlighting imperative role of senior nurses to deliver adequate training and advice to junior nurses to guarantee the avoidance of oversight or neglect of alarms.

Building on these observations, another nurse revealed that,

"According to my experience, there are numerous examples in the intensive care unit where staff, including nurses and technicians, have been unsuccessful in attending to alarms in a timely manner and silencing the alarms due to the overwhelming number of alarms going on simultaneously" (IDI participant 010)

This statement underscores the widespread problem of alarm overload and the difficulties encountered by healthcare practitioners, such as nurses and technicians, in effectively addressing a large number of concurrent alarms within the intensive care unit (ICU).

Hence, the aforementioned personal narrative highlights the considerable influence of excessive alarm activation on healthcare personnel's capacity to promptly and effectively

address urgent patient requirements, possibly jeopardizing both patient safety and the quality of treatment provided.

Theme 4: Alarm fatigue exists and is dangerous

This theme delves into the complex challenges encountered by healthcare professionals in the intensive care unit, particularly in relation to the persistent presence of alarms. The significance of these alarms lies in their role in ensuring patient safety by serving as indicators of potential issues with the patient. However, the persistent onslaught of stimuli might lead to the phenomenon known as "alarm fatigue," which is characterized by a diminished responsiveness among healthcare staff, potentially compromising the safety of patients. This theme examines the intricate phenomenon of alarm fatigue, analyzing its underlying factors, consequences, and the strategies employed by healthcare practitioners to mitigate the overwhelming auditory stimuli. The categories encompass a range of classifications: 1. Reasons for Ineffectiveness, 2. Desensitization Dilemma, 3. Consequences of alarm fatigue.

Category 1: Reasons for Ineffectiveness. The objective of this category is to provide insight into the factors contributing to the lack of attention or disregard towards alarms. This can be achieved by examining the root causes that diminish the efficacy of alarms, encompassing a spectrum of issues such as technical malfunctions and incorrect configurations. The reality of alarm fatigue in the intensive care unit (ICU) is influenced by multiple factors that lead to the inefficacy of alert responses. These aforementioned issues underscore the necessity of adopting a holistic approach to effectively tackle this pressing issue. One notable factor contributing to inefficient alarm responses is the inclusion of recently hired or inexperienced personnel who may not have had sufficient training on alarm systems, resulting in misconceptions regarding alarm importance or appropriate course of action.

As expressed by one participant:

"One reason is that we often have new interns or newly joined staff who lack proper hands-on training on alarm management..."(IDI participant 001)

This highlights the importance of implementing comprehensive training programs to ensure that all healthcare professionals, including new hires, are equipped to respond appropriately to alarm scenarios.

Overwhelming workloads in the intensive care unit can also lead to alarm neglect, as healthcare professionals may become preoccupied with other important duties and fail to recognize the urgency of alarm signals. This multifaceted workload can divert their attention away from alarms.

As one participant explained*:*

"Because the ICU is so demanding, it's simple to become bogged down in a lot of important chores. There are instances when the workload gets so bad that alarm signals might not get the prompt attention they need, which could cause responses to be delayed and patient care to be jeopardized" (IDI participant 011)

The remark made by the participant suggests that when the workload becomes overwhelming, there is a possibility that alarm signals may not be promptly attended to, which could lead to delayed reactions and impaired patient care.

Moreover, within the given environment, the prioritization of immediate patient demands may give rise to transitory instances where the identification of warning signs is overlooked, thereby causing delays in the initiation of crucial interventions or therapies.

As one participant states:

"The sheer volume of work in the intensive care unit can be overwhelming. Alarms may be briefly disregarded in the rush to provide patient care, which could cause delays in vital actions." (Participant IDI 011)

Moreover, hearing continuous noise can lead to confusion, making it difficult to differentiate between different alarm sounds or even determine how urgent they are. Multiple alarms going off at once in an intensive care unit (ICU) can be confusing for healthcare professionals and make it difficult to decide which alarm to prioritize and attend to first. The clamor of alerts can leave nurses feeling overburdened and unsure of how to react appropriately.

As one participant highlighted,

> “If the ventilator is alarming, the monitor is alarming, and the syringe pump is also alarming at the same time, they might not know which one to address first and how to respond" (IDI participant 001)

This situation underscores the complexity of alarm management in the ICU, where multiple critical devices may generate alarms concurrently, necessitating quick and accurate decision-making.

Another factor of alarm fatigue is high patient-to-staff ratios. A higher chance of alarms being disregarded arises when medical professionals are handling a large number of patients at once and may find it difficult to respond to every alarm as soon as it sounds. As one participant noted:

> “Mostly during break hours, when we have to handle two patients with multiple infusions what happens is that the staff tends to neglect alarms or fail to respond promptly to them. This sometime lead to potential safety hazards or delays in addressing critical issues..." (IDI participant 009)

The observation made by the participants highlights the correlation between heightened workload and multitasking with alarm management and patient safety. Specifically, it reveals that staff members have a tendency to overlook alerts or respond to them with delays during these stressful periods.

Healthcare personnel may experience desensitization and delayed response when alarm signals are routinely utilized to notify them of non-critical occurrences or artifacts. As one participant mentioned:

> "The repetitive false or technical error of some alarms causes staff to sometimes ignore them or silent the alarm altogether" (IDI participant 006).

Another nurse exclaimed:

> “When the alarm beeps we often feel that the alarm is due to artifacts and not a true alarm, so we might not respond because a minute ago it was the technical alarm that alerts on the monitor not the true one" (IDI participant 002).

This demonstrates how difficult it can be to discern between real and false alarms, which can undermine user trust in the alarm system and cause responses to be delayed.

Another nurse emphasized the disruptive nature of these false alarms. These disturbances have the potential to generate an atmosphere of distraction and heightened stress, which may hinder the healthcare team's capacity to deliver focused and prompt care to patients requiring assistance.

The nurse stated:

> “The occurrence of many false alarms not only has a disruptive impact on our workflow, but also poses a risk to our capacity to deliver timely and concentrated treatment, which may result in the neglect of key patient requirements.” (IDI participant 010)

This underscores the potential interruptions that healthcare personnel encounter while carrying out their crucial patient care responsibilities.

Another factor contributing to irresponsiveness to the alarms or alarm fatigue is lack of alarm customization. A nurse verbalized:

> “As per my experience of Team Leader for over 10 years, half of the alarms that are not valid is due to the fact that the bedside nurse has not customize the monitor alarm according to the patient’s baseline parameters.” (IDI participant 011).

Another Nurse expresses it as a patient safety concern. She started:

> “Lack of personalization makes it more difficult for us to respond promptly to critical alerts, which might endanger patient safety." (IDI participant 009)

The apprehension expressed by the participant highlights the possible hazards associated with alarm settings that are standardized or not personalized to individual needs. Such settings may result in delays in responding to critical patient issues and jeopardize the overall safety and welfare of those receiving treatment. The ability to customize alarm settings is of utmost importance as it allows for the alignment of alarm signals with the needs of individual patients. This customization eventually leads to improved accuracy and relevance of the alarm signals.

Category 2: Desensitization Dilemma. This section focuses on the psychological effects of constant alerts that cause a reduction in responsiveness. There's a chance that medical staff will begin to tune out alarms unconsciously or subconsciously if they sound too often.

Alarm fatigue presents a genuine dilemma within the healthcare setting, where staff may become desensitized to the constant sounding of alarms. This desensitization can have significant consequences for patient safety and care.

Some healthcare providers may take it upon themselves to modify alarm limits without proper authorization in an attempt to prevent frequent interruptions. As noted by one participant,

> "Some individuals may take it upon themselves to modify the alarm limits..." (IDI participant 005).

This action, while well-intentioned, can carry risks, as it may lead to alarm settings that no longer align with clinical best practices or patient needs.

Furthermore, the continuous beeping of alarms can, over time, become background noise, causing healthcare providers to become indifferent to critical alarm signals. As one participant explained:

> “The constant beeping can sometimes drown in the background and not catch attention" (IDI participant 003).

This observation highlights how the persistent nature of alarms can lead to desensitization among staff, potentially resulting in delayed responses to genuine clinical alarms.

Another participant note:

> “Continuous alarms can lead to nurses becoming desensitized to them” (IDI participant 005).

This sentiment underscores the need for ongoing efforts to address alarm fatigue and maintain the effectiveness of alarm systems in the ICU.

Another individual exemplifies the deliberate cognitive process necessary to maintain constant alertness in the face of repeated alerts.

He stated:

> “Repeated alarms have resulted in desensitization... Diminishing the distinction between threatening and non-critical alert, requires deliberate effort to be alert to actual crises despite the continual background noise." (IDI participant 010)

This statement underlines the need for implementing steps to reduce the impact of desensitization, such as focused staff training, modifying alarm parameters, and cultivating an environment of situational consciousness and good communication among healthcare teams.

Category 3: Consequences of alarm fatigue. Alarm fatigue has serious consequences that could jeopardize patient safety. This category looks at the consequences of missing or ignoring alarms and the bad things that can happen as a result. ICU patients may suffer serious, irreversible effects if alarms are ignored, which could have disastrous results. Interviewees emphasized how crucial it is to act quickly in response to alerts in order to stop unfavorable outcomes.

As one participant starkly expressed:

> "Even if you overlook one alarm, it can have dire consequences and can even lead to the death of a patient" (IDI participant 007).

This statement underscores the life-and-death significance of alarm responsiveness in the ICU and the potential for neglecting alarms to result in tragic outcomes.

Another participant shared a poignant example, explaining that:

> " ….. despite efforts to revive the patient, including performing CPR for approximately 25 minutes, it was futile, and the patient had already experienced brain death." (IDI participant 009).

This real-world incident serves as a sobering reminder of the importance of alarms in patient monitoring and the possible repercussions of disobeying them.

One more participant mentioning the consequences of missed alarm stated that:

> "The impact of alarm fatigue can't be underscored. Significant delays in patient care can result from missed alarms, jeopardizing their health and safety" (IDI participant 007).

The statement emphasizes the necessity of confronting alarm fatigue in healthcare institutions by implementing comprehensive strategies for reducing the risks linked to ignored alarms.

Alarm fatigue influences the healthcare system as a whole, not just on specific healthcare professionals. One of the major ramifications is that it might set off a chain reaction that causes problems with hiring and employee attrition.

As one of the nurses stated:

> "Alarm fatigue can have an unintended consequence, contributing to staff turnover and recruiting obstacles, that affect the whole healthcare system." (IDI participant 005)

This quote emphasizes the severe implications of alarm fatigue and illustrates how it affects the whole healthcare system in addition to the acute difficulties experienced by healthcare professionals.

Theme 5: Alarm Fatigue can be combated

This theme focuses on the tactics and measures that can be used to prevent the occurrence of alarm fatigue, guaranteeing that medical personnel stay alert, flexible, and capable of delivering the best possible care. This theme is divided into several sections that cover various aspects of alarm management, such as teamwork and staff education.

Category 1: Education and Training. The significance of regular instruction and training in reducing alarm fatigue is emphasized in this category. Healthcare personnel who receive ongoing education are better equipped to modify alarm settings based on the individual clinical requirements of their patients. ICU patients' safety and well-being are guaranteed by healthcare providers who are empowered to optimize the alarm system through workshops, practical sessions, and management involvement.

To combat alarm fatigue and make sure healthcare personnel have the information and abilities necessary to properly operate alarm systems, ongoing education and training are essential. Interviewees acknowledged the importance of continuing education and training in reducing alarm fatigue.

Staff can choose alarm settings wisely and guarantee that alarms are customized to the patient's clinical condition by being educated about alarm systems and their importance.

One participant explained:

"Well, in this regard, we can provide education to our staff members. As a TL (Team Leader) or even as a staff nurse, we can offer education about what alarm fatigue is and what settings need to be adjusted based on the patient's clinical condition" (IDI participant 001).

This approach empowers healthcare providers to optimize alarm systems for patient safety.

Management also plays a crucial role in addressing alarm fatigue by providing timely and proper training to their staff and emphasizing the importance of clinical alarms. As one participant highlighted:

"Management can play a role in this by providing timely and proper training to their staff, emphasizing the importance of clinical alarms" (IDI participant 005).

This emphasizes how important it is for leaders to promote a culture of alertness and responsiveness.

In addition, practical workshops and sessions were found to be efficient ways to close the knowledge gap between theory and practice in actual intensive care units.

One participant emphasized:

"Hands-on workshops and practical sessions can bridge the gap between theoretical knowledge and its application in real-time ICU settings" (IDI participant 008).

Healthcare professionals can acquire hands-on experience in handling alarms and effectively handling emergency situations with the help of these interactive training methods.

Category 2: Role modelling. This category highlights the team leaders' pivotal role in addressing alarm fatigue within the healthcare setting. Participants perceived the guidance,

support, and supervision of team leaders as a significant contributor to managing alarms effectively by the staff members thus ensuring patient safety. One key aspect of a team leader's role in addressing alarm fatigue is their ability to notice when alarms are sounding and offer assistance promptly.

This sentiment was elucidated by one participant highlighted:

> "As a team leader, you should also notice when an alarm is beeping and offer assistance" (IDI participant 003).

This proactive approach ensures that alarms are not overlooked, and healthcare providers receive the support they need to respond effectively.

Effective alarm management can also be facilitated by putting procedures in place like making thorough rounds at the beginning of a shift at the patient's bed. During these rounds, team leaders evaluate the patient's condition and alarm settings to spot possible problems and make the necessary corrections.

As one participant explained:

> "In our practice, at the start of the shift, we conduct a complete bedside round, assessing the patient's condition" (IDI participant 005).

This practice helps ensure that alarm settings are aligned with the patient's clinical condition and reduces the risk of alarm fatigue.

Another Participant verbalize:

> “In this capacity, we highlight the significance of adequate education and training to provide our team with the expertise and abilities needed to address alarm fatigue adequately."(IDI participant 004)

This highlights the critical role that team leaders have in advocating for education and instruction to deal with alarm fatigue.

Category 3: Balancing and partnering. Even with all of the alerts going off, healthcare workers still have a lot of work to do. This category looks at how they manage to balance their responsibilities with the requirement to respond to every alarm. One of the biggest challenges in intensive care units (ICUs) is juggling alarm responses with other tasks. Healthcare providers use a variety of tactics to handle this intricate part of patient care. Interviewees stressed how critical it is to respond to alarms right away, particularly when they seem to be indicating potentially fatal situations.

ICU nurses employ a crucial tactic of varying alarm volumes to enable them to perceive and react to alerts efficiently while juggling their other responsibilities. This demonstrates their commitment to addressing alarms promptly. As one participant emphasized:

> "...if an alarm is sounding, the first thing is to assess it and find out if it's truly due to the patient's clinical condition deteriorating or if there's another reason for the alarm" (IDI participant 001).

Participants acknowledged that temporary alarm neglect can occasionally result from the sheer volume of tasks, particularly when dealing with unstable patients. To guarantee prompt responses in these situations, safety precautions like centralized monitoring systems are activated. As one participant mentioned:

> "...we have a central monitoring system where the team leader or the person at the counter immediately responds to alarms..." (IDI participant 009).

This approach ensures that alarms are not overlooked even when the primary nurse is occupied with other critical tasks.

Additionally, when there is a high patient-to-staff ratio, it is frequently the duty of other team members to help tend to alarms while the primary nurse is attending to another patient. As one participant explained:

> "...if a new patient comes to us or if there is a crisis with another patient, the assigned staff or other team members respond immediately and take appropriate action" (IDI participant 009).

This collaborative approach helps ensure that alarms are addressed promptly, even in demanding ICU environments.

Partnering / teamwork is also another factor which is essential for controlling alarm fatigue. Patient care is always given top priority, and all alarms are responded to promptly thanks to new staff orientations, shared responsibilities, and mutual support. When a team works together, there is less chance of alarms being overlooked and patient care always takes precedence. In a healthcare setting, cooperation and teamwork are essential for managing alarm fatigue. In order to ensure efficient alarm management, interviewees emphasized the value of staff members helping one another and experienced staff members mentoring and guiding new hires.

One tactic that was brought up was teaching employees to set an alarm threshold, especially when new employees join the team. This introduction to common alarm thresholds aids in ensuring that alarms are set correctly and do not cause needless alarm fatigue. As one participant suggested:

> "Hmm, another thing we can do is train our staff to have a certain threshold for setting alarms. For instance, when a new staff member joins, we team can orient them to have a standard alarm threshold" (IDI participant 003).

In alarm management, sharing duties and supporting one another was another essential component of teamwork. Participants underlined that the patient should always come first and that treating the patient and stabilizing their condition should take precedence if a clinical alarm signals instability.

One participant expressed this sentiment, stating:

> "Being a critical care nurse, our primary focus is on the patient. If a patient's clinical alarm beeps, it indicates that the patient is not clinically stable. Our first priority is to attend to the patient and stabilize their condition no matter whose patient is that" (IDI participant 007).

Furthermore, it was believed that teamwork in a hectic intensive care unit was crucial to spotting missed alarms and making sure nothing was overlooked. Healthcare professionals depend on one another to keep alarm management at a high standard of vigilance.

As one participant emphasized:

> "In a busy ICU environment, working as a team helps in catching overlooked alarms, and we all rely on one another to ensure nothing gets missed" (IDI participant 010).

In conclusion, the argument emphasizes how collaboration in the intensive care unit (ICU) protects combat alarm fatigue and guarantees that alarms are handled quickly and efficiently. It highlights how dependent team members are on one another to maintain patient safety and offers a strong illustration of why collaboration is crucial in healthcare environments.

Category 4: Enhancing wellbeing. Our research showed that alarm fatigue has important psychological components in addition to its technical ones. This category highlights how crucial it is to attend to the health of healthcare professionals in order to guarantee that they are able to handle alarms in an efficient manner. Relaxation, forums for raising issues, ongoing educational activities, and ensuring regular breaks to recharge and

improve alertness are all stressed. In order to manage alarm fatigue, make sure that healthcare personnel can respond to alarms effectively, and ensure that they can carry out their duties, it is important to address the mental health of healthcare staff. Interviewees underlined how critical employee wellbeing is to alarm management. The key to enabling staff members to handle alarms effectively is ensuring that they are psychologically calm and well-rested. One participant recommended:

> "Just try to keep the staff as relaxed as possible and staff will make an effort to help them out if their alarms are beeping repeatedly" (IDI participant 003).

This approach recognizes that well-rested and relaxed staff are better equipped to handle the stress and demands of the healthcare environment, including responding to alarms promptly.

Giving employees the chance to express their worries, frustrations, and requests for assistance can be extremely beneficial to their mental health.

Stress reduction and improved focus on patient alarms have been linked to staff training sessions where they can review and refine specific procedures or aspects of their roles. As one participant mentioned:

> "...there should be sessions where staff can learn and revise certain things repeatedly so that the worries of adequately response to the alarms is handled" (IDI participant 003).

This ongoing education and support can help staff members feel more confident in their abilities and better prepared to respond to alarms.

Additionally, ensuring that staff have regular breaks and mental refreshers was highlighted as a strategy to improve their focus on patient alarms.

As one nurse noted:

"Ensuring regular breaks and mental refreshers for staff can significantly improve their focus on patient alarms" (IDI participant 009).

Breaks and opportunities for relaxation can rejuvenate staff and enhance their alertness and responsiveness.

Conclusion

In conclusion, our findings give a holistic picture by combining the findings from the interviews, flow sheet data, and camera observations. It is emphasized that there is a dire need for standardized alarm settings, continuous training of nursing staff, and introducing effective strategies to combat alarm fatigue, ensuring quality patient care.

Discussion

The current chapter is partitioned into two distinct pieces. The initial segment of the chapter provides an analysis of significant study results and compares them with the existing body of research information. The subsequent part examines the study's strength, constraints, ramifications for further investigations, and suggestions. The study was motivated by the subsequent research inquiries: “What are the critical care nurse’s responses to various clinical alarms in critical care?” and “What are their experiences regarding alarm fatigue, in the intensive care unit of a tertiary care hospital?” This study examined the important function of clinical alarms in one of the private tertiary health care institutions relating to patient safety and the provision of optimal care. Nurses were interviewed to understand their perception about alarms existence at ICU, their response rate time and process, any challenges these alarms pose on nurse’s practice and ways to overcome them. Simultaneously, a comprehensive document observation that gave a view of how alarm settings are aligned with the established protocols. Moreover, CCTV footage was also observed also done in ICU to better discern the practical environment in which these alarms are operated. The camera observation helped to determine the alarm response times, the frequency of false alarms and issues associated with alarm fatigue experienced by nurses. The core findings and linking interviews, documents observation and camera observations, provide overall review to offer insight into clinical alarm systems being used in the hospital.

Five major themes that emerged from the IDIs are as follows:

1. Alarm setting guarantees patient Safety.
2. Alarms response follows standards and patient priority.
3. Alarm’s driven nurse’s actions.
4. Alarm fatigue exists and is dangerous.

5. Alarm fatigue can be combated.

Summary of the findings

The study established that clinical alarms are crucial for avoiding patient injury, signaling clinical developments, and promoting careful patient care practices. All participants stressed the need for alarm standardization based on institutional policy and patient-specific adjustment of alarms to optimize alarm settings. However, there exists discrepancies in actual settings of alarms and their response time for different clinical parameters such as heart rate, systolic and diastolic blood pressure, and SpO2 saturation levels, as compared to their standards. Moreover, many false alarms and the issue of alarm fatigue also came at the surface giving rise to skepticism about the accuracy and dependability of alarm mechanisms. Alarm fatigue, being the major finding of the study, came out to be the reasonof alarms mismanagement and inaccuracies. The discussion part will highlight issues contributing to alarm fatigue its effects and possible solution.

Alarm setting guarantees patient safety

The present study revealed the crucial role of clinical alarms in ensuring patient safety within healthcare settings. These alarms were perceived by the respondents as extremely important for mitigating or preventing adverse events by warning the ICU staff as well as offering continuous monitoring of patient conditions. These findings are in line with the current literature where studies have shown that alarms are perceived as indicators of a patient's clinical status, monitoring of vital signs, and highlighting any potential deterioration in patient conditions, thereby ensuring timely intervention (Bach et al., 2018; Fontana, 2018).

However, the present study also revealed how alarm fatigue has a negative influence on patient safety. Alarm fatigue arises when nurses become sensitized to the number of

alarms they are exposed to; hence, they do not react to essential ones promptly (Bi et al., 2020).

In accordance with the current findings, another author also revealed that nurses consider continuous alarms to be a nuisance and intrusive to patient care in intensive care settings (Lewandowska et al., 2020). To add to this challenge, the study also pointed out that there is no distinct system for managing alarm settings. Other studies also stressed the importance of patient safety in alarm system design (Johnson et al.; Shivers et al., 2013). They emphasized the need to consider alarm fatigue and usability issues throughout the design process, especially as new technologies introduce more complex alarms. Ensuring patient well-being should be the primary focus, with an eye on regulatory and liability considerations.

Alarms response follow standards and patient priority

The current study highlighted the importance of standardized protocols for alarm settings to ensure uniform responses to clinical alarms. This was perceived by the respondents as a crucial element to help maintain high safety standards and team cooperation in the ICU setting. However, the study also recognized the need for patient-specific customizations, where alarm settings are specified as per the individual patient's need in order to avoid unnecessary and intrusive alarms. Respondents perceive these individual adjustments crucial to ensure that critical changes in patient status are not missed as well as unnecessary alarms can be minimized. This finding of dual approach of standardization and customization aims to optimize patient care is supported by literature, thus reducing the incidence of alarm fatigue among healthcare providers, and enhancing overall patient safety (Fujita & Choi, 2020; Ruppel et al., 2018).

The present study aligns with existing literature, emphasizing the necessity of implementing system designs tailored to individual patient needs. This includes the customization of thresholds to enhance patient care. (McGrath et al., 2016). Ruppel et al. (2018) in fact, revealed that installing software support for customization of alarms to cater individual patient needs resulted in reduction of irrelevant alarms and nurses reported that they spent less time on non-actionable alarms post-intervention and thus less disturbance was experienced by them.

The current findings suggest that in the context of AKUH/Pakistan, use of a well-implemented alarm system that blends standardization with the ability to customize settings to cater to each individual's clinical needs can lead to a less disruptive workflow for healthcare professionals.

Alarm driven nurse's responses

The study underlines the critical role alarms play in guiding nurses' actions in healthcare settings, particularly in intensive care units (Ramlaul et al., 2021). Nurses rely on the alarm system to signal potential dangers and to prompt swift, life-saving measures, such as adjusting a patient's medication or managing a ventilator. However, respondents believed that alarm fatigue can lead to ignoring or disabling alarms, especially among junior staff who are not well-trained, raising concerns about patient quality and safety. These findings also call for proper training and management of alarm systems. The balance between responding to alarms and preventing alarm fatigue is essential for ensuring effective and safe patient care in high-pressure environments like ICUs.

The present study further revealed that life-threatening alarms, classified as Level 1 alarms, occurred 10 times during the observation period. Alarm response times varied, with a mean response time of 1.8 minutes. Alarm response is critical in such cases, as any delay can

have life-threatening consequences. Worryingly, only half of these Level 1 alarms received timely responses, while the others were either ignored or, in one instance, automatically switched off due to the absence of a registered nurse at the bedside. Similar findings are revealed that the increased exposure to non-actionable alarms lead to an increased response time (Paine et al., 2016)

Alarm fatigue exists and is dangerous

The current study illustrates that the issue of alert fatigue is well acknowledged in our environment. The answers disclosed that alarm fatigue arises from a pervasive desensitization of staff to routine alerts, leading to prolonged response times and potentially compromising patient safety. The current investigation unveiled that the origins of alarm fatigue are multifaceted. Alarm fatigue is a syndrome resulting from an abundance of alerts, insufficient staff experience, an overwhelming ratio of patients to staff, false alarms, and a lack of customized alarm settings for varied situations. For example, as a result of the high frequency of false alarms, caretakers may become desensitized to important alarms, which might result in fatal consequences. Enhancing patient safety can be achieved by implementing enhanced staff training, refined alarm system design, and an efficient alarm management strategy.

These findings are in accordance and consistent with other studies that were undertaken, and they provide insights for discourse and comparisons (Bourji et al., 2020; Jeong & Kim, 2023; Lewandowska et al., 2020; Nguyen et al., 2020) . Bourji et al, 2020 emphasized that alarm fatigue is a significant patient safety concern in critical care settings. Their study revealed that clinicians frequently encountered false alarms, leading to alarm desensitization. Alarm fatigue was reported more frequently among physicians and registered nurses, and it was significantly associated with stress. Similarly, a study by Lewandowski et al, 2020 highlights how nurses of intensive care perceive alarms as burdensome and too frequent, ultimately interfering with patient care. The study highlighted the need for effective

alarm management strategies and measurements of alarm fatigue levels, which aligns with the challenges identified in the present study

Similarly, in accordance with the present findings, Jeong and Kim (2023) identifies frequent false alarms as a significant issue and calls for standardized alarm management protocols, proper education, and training to address alarm fatigue. Samantha Deck's work (2016) emphasizes alarm fatigue as one of the potential reasons for patient deaths and other serious injuries caused by negligence. This stresses the urgent need to come up with specific policies that are designed to tackle this problem (Deck, 2016).

This problem occurs due to the low nurse/patient ratio within local healthcare facilities, whose staff usually needs to be more experienced. Hundreds of alarm calls with little knowledge of handling alarms result in sensory overload and overburden healthcare providers.

Alarm fatigue can be combat

Adoption of appropriate approaches can minimize alarm fatigue as a major problem in clinical institutions. The participants indicated that education and training of staff is vital so staff can tailor each alarm to specific patient needs and thus reduce unnecessary fatigue. The team leaders are crucial to demonstrating good alarm management while assisting. Shared responsibilities and technologies like centralized monitoring provide balance in meeting clinical duties and alarm response. Providing relaxation, as well as support forums with intervals of regular breaks, is necessary for concentration and prompt reaction. Taken together, these multiplex solutions enhance the safety and quality of care for patients.

Speich (2017) conducted a quality improvement study aimed at reducing alarms, particularly noncritical and false alarms, to combat alarm fatigue. The study findings support the notion that addressing alarm fatigue requires a multifaceted approach. A statistically

significant reduction in alarm frequency rates following interventions, indicating that strategies targeting specific types of alarms can have a positive impact. This resonates with your findings about the challenges of distinguishing between true and false alarms and the need for comprehensive solutions.

The present study supported adjusting alarm parameters based on specific patients' requirements. Standardized policies give a starting point for alarm configuration, but adjusting these parameters based on individual patient needs and desired outcomes during monitoring is often necessary. This shows that healthcare is dynamic, and alarm settings should consider the complexity of each patient's clinical condition. Effective alarm prioritization in the ICU ensured that life-threatening alarms were responded to first. Such a patient-centered approach to alarm management is critical to optimizing patient care and safety. This means that a blanket approach in setting alarms may not be the best approach, and hospitals have to consider the specific needs of patients.

The significance of alarm settings prioritizing the patient's needs is a crucial aspect of healthcare administration, in this regard the findings of the current study coincide with the existing body of literature (Cho et al., 2016; Sebastian & Brown, 2018; Speich, 2017; Thangavelu et al., 2015). Several studies offer valuable perspectives on customizing alarm settings to suit each patient's requirements and addressing alarm fatigue. For example, Sebastian and Brown (2018) identified the issue of false alarms and stressed the necessity for personalized alarm configuration. They highlighted the need to tailor alarm parameters to meet individual patient needs, which aligns with the current findings regarding the ever-changing nature of healthcare and the need for customized alarm settings. This customization is vital in reducing excessive alarm frequency and diminishing alarm fatigue. Likewise, Thangavelu et al. (2015) further emphasizes the importance of tailoring response times for alarms based on their level of risk. Their research suggests that adopting a patient-centered

approach to managing alarms, where response times are adjusted according to urgency, can enhance user response rates, and help prevent alarm fatigue. This aligns with the conclusion of the present study that healthcare institutions should consider individual patient needs when configuring alarms.

A few studies also explored the possible mitigation strategies for prevention of alarm fatigue and their impact on patient safety. Pascale (2018) discusses the challenges associated with bedside patient monitoring systems and explores alternative solutions like head-worn displays (HWDs). While HWDs have the potential to reduce alarm mismanagement, their mixed results indicate the need for careful consideration and design in implementing such technologies. This highlights the need for ongoing search for effective patient-centered alarm solutions.

Policy Implications

The results from the studied cases suggest the need for policy implementation strategies aimed at combating alarm fatigue for the safety of patients in healthcare facilities. Alarm fatigue is a major danger to patients' health and calls for strict policies to be implemented. A crucial component of these regulations is the establishment of precise and uniform recommendations for reaction times in response to various alarm criticality levels, which distinguish between life-threatening (Level I) and possibly life-threatening (Level II) scenarios. These guidelines are intended to give nurses clear guidelines on how quickly they should respond to warnings with different levels of criticality. Healthcare institutions can improve patient safety and quality of care by reducing the effects of alarm fatigue, increasing the efficacy of alarm systems, and establishing such specific and differentiated response time requirements.

Implementation of Alarm Management Protocols

Healthcare establishments must establish and enforce all-encompassing alarm management protocols that incorporate explicit instructions on the customization of alarm configurations to suit the specific requirements of each patient. This includes prioritizing alarms based on their clinical urgency and implementing systematic methods to decrease the occurrence of false positive alarms.

Staffing and Training Regulations

There must be adequate staffing levels to ensure an appropriate ratio of patients to nurses, thereby lessening the mental burden on healthcare providers and alleviating the problem of alarm exhaustion. Furthermore, it is essential to make regular, obligatory training for staff on managing alarms, adhering to response protocols, and staying updated with advancements in patient monitoring technology, a requirement.

Standardized Response Times

Implementing a policy that outlines predetermined timeframes for responding to alarms of different levels to prioritize and promptly address high-priority alerts that pose life-threatening risks (e.g., one minute for Level I alarms). The objective is to enhance patient outcomes and to ensure success and adherence to this policy, regular audits should be conducted. By embedding these policies into healthcare governance, institutions can systematically address the challenges associated with clinical alarms, thereby improving patient safety and enhancing the working conditions of healthcare professionals.

Recommendations

Several important recommendations to address the problems related to alarm settings, alarm fatigue, and patient safety in healthcare contexts arise from the qualitative results, observations, and flowsheet interpretations in this study. These suggestions are meant to

increase the accuracy with which vital signs are monitored, the promptness with which medical professionals respond to crucial alerts, and the overall quality and safety of patient care.

Enhanced Alarm Configuration and Customization. A system for the dynamic customization of alarm settings, and parameters that can adapt to the evolving clinical status of patients need to be developed. This involves creating a protocol for setting alarm thresholds and volumes based on individual patient needs and risk profiles, potentially incorporating machine learning algorithms to predict and adjust according to patient-specific scenarios. Continuous training should be provided to staff to ensure they are proficient in using these advanced features.

Enhance Training and Education. Investing in comprehensive education and training programs for healthcare professionals, especially nurses, to help them understand the importance of alarm fatigue and providing them with the tools they need to appropriately handle alerts. Appropriate alarm response procedures, methods for separating important alarms from non-critical ones, and the significance of prompt actions should all be included in training.

Regular Skills Assessment. There is a need to conduct regular competence evaluations to gauge healthcare practitioners' alarm management expertise. The purpose of these evaluations needs to be to pinpoint any areas that call for more guidance or assistance. To close identified gaps, ongoing education and skill development should be provided.

Continuous Quality Improvement. Improvement can be made by implementing a culture of continuous quality improvement in alarm management. For example, encouraging healthcare staff to report instances of alarm fatigue or concerns regarding alarm settings.

Moreover, reported incidents and near-misses should be regularly reviewed to identify opportunities for improvement and to implement corrective actions.

Research and Innovation. Support should be provided for ongoing research and innovation in alarm management technology and practices. Moreover, health care facilities should collaborate with researchers and industry experts to explore new solutions for reducing alarm fatigue and improving the system.

Strengths of the Study

As per the researcher's knowledge, this is the first study of its kind in Pakistan that has explored nurse's experience of alarm response and alarm fatigue and generated contextually diversified knowledge about the phenomenon. The finding can sensitize nurses so that they can understand the importance of effective alarm management. Moreover, one of the major strengths of the present study is the comprehensive data collection process. The study gathered a considerable amount of data from diversified sources, allowing for a comprehensive analysis of alarm fatigue and alarm settings within the healthcare environment. This approach provided a more holistic understanding of the alarm management issues, allowing for in-depth insights through interviews and statistical analysis of observations and flowsheet data.

AACN Synergy model

Optimizing patient care in the critical care unit requires the Synergy Model to be integrated in the setting of alert fatigue. The Synergy Model offers a framework that can handle the problems caused by alarm fatigue because of its emphasis on matching nurse abilities with patient demands. Through the customization of alert levels to meet each patient's specific needs, the Synergy Model enables a synergistic approach to care delivery. This approach not only fit in with the Synergy Model's holistic, patient-centered care but it

also offers an organized strategy to reduce unnecessary notifications, ease alarm fatigue, and improve overall patient safety and wellbeing. Including the concepts of the Synergy Model into alarm management plans appears to be a viable way to promote a critical care setting that is more patient-centered and responsive.

Limitations of the study

- **Single-Center Study**. The study was conducted at a single healthcare institution, which may limit the generalizability of its findings. Alarm management practices and challenges can vary across different healthcare settings, so the results may not be representative of all hospitals or clinics.
- **Lack of Patient Perspective.** The study primarily focuses on healthcare providers' experiences and responses to alarms. It lacks the perspective of patients who are directly impacted by alarm management. Hence patient perspective could have provided valuable insights into the patient-experience.

Despite these limitations, the study provides valuable insights into alarm fatigue and alarm settings within the healthcare context. It offers practical recommendations for addressing these issues and underscores the importance of patient safety in alarm management policies and practices.

Study Implications

The study has the following implications related to nursing education, nursing research and nursing practice.

Nursing Education. The investigation into the reaction to alarms and the phenomenon of alarm fatigue among nurses in the intensive care unit (ICU) requires a reassessment of nursing education curriculum. The results emphasize the significance of incorporating specialized training modules into nursing programs that especially tackle the difficulties related to alert management. Implementing curriculum modifications could provide nursing

students with the necessary skills and knowledge to identify and appropriately address stressors associated with alarms. In addition, integrating realistic simulation training within the educational framework would offer students practical experiences in maneuvering through high-pressure, alarm-laden settings. The proactive strategy seeks to enhance the readiness of upcoming nurses to effectively handle the distinct difficulties presented by alarm fatigue in critical care environments.

Nursing research. This work establishes a fundamental basis for next nursing research, stimulating a more thorough examination of the intricate elements that contribute to alarm fatigue and its wider consequences. Expanding on this investigation, researchers should further examine the categories of alarms that have the greatest impact on fatigue, the frequency of false alarms, and the potential associations between alarm fatigue and patient outcome. Future research endeavours may prioritise the creation and evaluation of interventions designed to reduce alarm fatigue. These interventions would attempt to assess their efficacy and investigate their effects on the well-being of nurses as well as patient care results. Moreover, doing longitudinal study is essential for comprehending the trajectory and enduring impacts of alarm fatigue on the mental well-being and job contentment of nurses over an extended period.

Nursing Practice. The findings of this study have practical implications for making improvements in nursing care within the ICU setting. The study's conclusions may prompt hospitals and healthcare institutions to reconsider their policies and practices regarding alarm systems. This may entail modifying alarm specifications, adopting novel technologies specifically designed to mitigate false alerts, and applying optimal strategies to minimize undue burden on nursing personnel. In order to acknowledge the negative impact of continuous exposure to alarms on nurses, institutions should consider offering supplementary

support mechanisms, including stress management tools, counselling services, and measures to mitigate burnout. Additionally, the study emphasizes the possibility of technological progress, asking hospitals to investigate and allocate resources to intelligent alarm systems that differentiate between critical and non-critical alarms. This would result in a more efficient and less demanding work environment for ICU nurses.

Summary of the chapter

This chapter presents the study's findings in relation to evidence-based literature. The majority of the study's findings were in line with the existing body of knowledge on response to alarms and alarm exhaustion. Ultimately, the study's strengths, limitation, consequences, and suggestions were thoroughly examined.

Conclusion

To sum up, this study has sheds light on the complex web of issues surrounding alarm management and explores the important topic of alarm fatigue in hospital settings. It has produced important results and highlighted implications for the healthcare sector using a mix of flowsheet data analysis, real-world observations, and qualitative interviews.

This study's primary finding is the disparities in alarm settings for monitoring vital signs. Different alarm settings for heart rate, systolic and diastolic blood pressure, and SpO2 saturation levels were found, according to our investigation. Thus, the precision and dependability of vital sign monitoring are called into question by these discrepancies, which ultimately compromise patient safety. To guarantee early diagnosis and suitable patient care, addressing these discrepancies and putting in place standardized alarm settings are essential first steps.

The current research also explores the possible effects of alarm fatigue on patient care and safety. Alarm desensitization is a serious issue, as seen by the lengthier reaction times to

urgent level 1 alerts, which should ideally demand quick care. The majority of healthcare professionals were found responding more slowly than the suggested 10 seconds, which emphasizes the necessity for proper training and consistent reaction times. Life-threatening alerts should never be ignored; failing to do so can have serious repercussions, including poor patient outcomes.

Drawing on knowledge from previous research and current findings, many policy recommendations has been provided. These include creating alarm management training programs, modifying alarm settings to reduce nuisance alerts, and specifically specifying response times for critical alarms. Healthcare facilities may greatly decrease alarm fatigue, increase patient safety, and raise the standard of care by solving these problems.

This study is essentially a wake-up call for the healthcare sector. Alarm fatigue is a complex issue that affects patients and healthcare professionals in many ways. It is important for everyone to work together to rethink alarm management procedures so that alerts become a tool for patient safety rather than a cause of annoyance and exhaustion.

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Table 4:

Literature Review

Author(s)	Year of Publication	Purpose of Study	Study Design	Sample and Sample Size	Key Findings
Albert et al.	2015	Comparing the efficacy of disposable EKG lead wires and reusable wires	Prospective, cluster-randomized, controlled, and blinded design	Four inpatient telemetry units	Disposable wires led to a 29% risk decrease compared to reusable wires, but there was no difference in the number of genuine emergency alerts and erroneous alerts, between the two groups.
Andrade-Méndez et al., 2020	2020	Observe the reaction times, clinical significance of alarms, and alarm fatigue in an adult intensive care unit.	A descriptive, quantitative, observational research design	120 hours of non-participant observation over the course of three months.	The study concludes that there is alarm fatigue and that clinically significant alarms are more prevalent in the medium and low ranges. To combat alarm fatigue and improve ICU patient response to crucial alarms, improvement measures are required.
Bosma & Christopher	2023	Aimed to reduce alarm fatigue and improve nursing competency in managing	Quality improvement experiment	115 nurses	The CEASE bundle was found to have a positive influence on nursing practice.

		alarms by implementing the CEASE model			
Brantley et al.	2016	To determine how pulse oximetry alarm rates were affected by a training session on customizing alarm settings	Quasi-experimental study	Nurses from Emory University	39% decrease in pulse oximetry alerts following the learning session
Christensen et al.	2014	To learn more about nurses' opinions on the existing methods used for clinical alarm management and alarm settings	cross-sectional	48 nursing staff	The results confirmed the premise that too many alerts can lead to desensitization and decreased reaction times, which can result in the silence or silencing of alarms without proper reason.
Clochesy, Cifani, and Howe	1991	To evaluate appropriate skin preparation for electrode placement	Randomized control trial	Not specified in the article	Preparing the skin by cleaning it and making it slightly rough helped to reduce artifact, which is known to cause false alarms.
Drew et al.	2014	To study false alarm rates and possible changes in observational	Observational research	77 patients	88.8% of audible arrhythmia alarms were mistakenly positive

		methods to reduce them.			
Ergezen and Kol	Between August 2016 and January 2017	to investigate the types of monitor alarms in an adult intensive care unit (ICU) and how nurses responded to them.	observational study	13 registered nurses were observed	The study found that a significant number of alarms did not reflect the actual clinical status of the patients, indicating a high rate of false alarms. Additionally, as the number of false alarms increased, the response rate of nurses to these alarms decreased
Honan et al.	2015	To expand on previous studies and identify themes in nurses' comments regarding clinical alarm management	Qualitative analysis	410 nurses	Six themes emerged: dissonance and desensitization, pollution, panic and pathology, demanding responsibility, demanding the authority of nurses, and clinical alarm management being essential but not a magic bullet. Comments emphasized worry about potential danger and recommended enhancements.
Inokuchi et al.	2013	To review alert relevancy and determine the	Prospective observational study	18 patients at the medical intensive care unit (ICU) of	Only 6.4% of all alerts were clinically

		clinical appropriateness of alarms.		the University of Tokyo Hospital	appropriate, and combining physiologic data resulted in a 21.4% reduction of clinically irrelevant alarms.
Joy	2014	To address the issue of clinical alarm fatigue and patient anxiety caused by frequent and unnecessary cardiac monitoring alarms and to develop more effective monitoring practices.	Observational study	Boston Medical Center	The pilot study successfully decreased audible alarms by 89%. Nurses were satisfied with the alarm changes, with 64% rating the noise level as acceptable.
Honan et al.	2015	To expand on previous studies and identify themes in nurses' comments regarding clinical alarm management	Qualitative analysis	410 nurses	Six themes emerged: dissonance and desensitization, pollution, panic and pathology, demanding responsibility, demanding the authority of nurses, and clinical alarm management being essential but not a magic bullet. Comments emphasized worry about potential danger and

					recommended enhancements.
McGuffin & Ortiz	2019	To investigate whether changing ECG electrodes daily could reduce the frequency of nuisance alarms	quantitative/comparative design.	36-bed adult inpatient cardiac telemetry unit	The results indicated a significant reduction in telemetry alarms following the implementation of daily electrode changes. Post-intervention data showed a 74.15% decrease in alarms compared to pre-intervention levels.
Medina, Clochesy, and Omery	1989	To evaluate appropriate skin preparation for electrode placement	Randomized control trial	Not specified in the article	Preparing the skin by cleaning it and making it slightly rough helped to reduce artifact, which is known to cause false alarms.
Ruppel et al.	2018	To examine the approaches of ICU nurses towards customizing electrocardiograph (ECG) monitor alarms to reduce alarm fatigue in intensive care units (ICUs).	convergent mixed methods design	27 nurses	The interviews revealed that customization practices varied greatly among nurses and were influenced by factors such as clinical expertise, lack of education on customization, and negative experiences.

Sendelbach et al.	2015	To examine the effects of bundle interventions on reducing alarms	Pre post interventional study	Not specified in the article.	The number of alerts per monitored bed per day decreased by 61% and 88.5%, respectively, because of the bundle interventions
Speich	2017	To determine if daily electrode replacement on patients may lower the frequency of ECG technical alerts	Quality improvement experiment	Not specified in the article	Daily electrode replacement and following skin preparation protocols resulted in a significant drop in alarms
Turmell et al.	2017	Evaluate the effectiveness of AACN bundle measures.	quasi-experimental	580 patients	AACN bundle measures reduced alert rates by 30%
Walsh-Irwin and Jurgens	2015	To examine the effect of adequate electrode positioning and preparation of the skin on the number of ECG alarms	Pre-post intervention study	15 patients	Hair was clipped as necessary, the skin was washed with soap and water, dried with a washcloth, and electrodes were attached to leads and properly positioned. The alert rates dropped from 1341 to 992 in 24 hours, or a 44% decrease

Wung et al	2018	Too determine which equipment causes most sensory overload among critical care nurses	Qualitative study, Focus group interview	who worked for more than 20 hours per week for over the past 6 months	The respondents stated that the alarms from cardiac monitors, ventilators, and intravenous pumps were the most helpful and contributed the most to sensory overload. Electronic health record alerts and medication delivery systems' alerts/alarms were regarded as being the least beneficial and least likely to cause sensory overload.

Appendix A

ERC Permission

آغا خان یونیورسٹی
THE AGA KHAN UNIVERSITY

30-Mar-2023

Dr. Rubina Barolia
Department of School of Nursing and Midwifery
Aga Khan University
Karachi

Dear Dr. Rubina Barolia,

2023-8351-24458, Rubina Barolia: "Exploring experiences of alarm response and alarm fatigue among nurses working at ICU of a tertiary care hospital in Karachi Pakistan",

Thank you for submitting your application for ethical approval regarding the above mentioned study.

Your study was reviewed and discussed in ERC meeting. There were no major ethical issues. The study was given an approval for a period of one year with effect from 30-Mar-2023. For further extension a request must be submitted along with the annual report.

List of document(s) approved with this submission.

Submission Document Name	Submission Document Date	Submission Document Version
CITI certificate	05-Aug-2020	CITI program
certificate of NIDA	28-May-2021	Certificate of NIDA
citiCompletioncertificate9047815	01-Feb-2023	1
proposol shehnila revise final	19-Feb-2023	1
CMO permission letter revised	19-Feb-2023	1
CNO pdf	19-Feb-2023	1
consent form urdu	02-Mar-2023	1
Consent form english 1	07-Mar-2023	1
Affidavit for Translation consent and interview guide	07-Mar-2023	1
interview guide	22-Mar-2023	2
Study guide	22-Mar-2023	2
interview guide in urdu	22-Mar-2023	2

Appendix B

Permission letter from Chief Medical Officer

آغا خان یونیورسٹی
THE AGA KHAN UNIVERSITY

Dated: February 13, 2023

Title: Exploring experiences of alarm response and alarm fatigue among nurses working at ICU of a tertiary care hospital in Karachi Pakistan

Principal Investigator: Dr. Robina Barolia
Associate Professor, School of Nursing
Aga Khan Hospital
Karachi

The above-entitled study is a exploratory methodology study in the Aga Khan University Hospital, Karachi.

As Chief Medical Officer at the Aga Khan University Hospital, Karachi, I approve the above named study to be conducted within the Hospital, following required approvals and maintaining compliance with all Institutional ethical and regulatory requirements

Asim F. Belgaumi,
Professor, Pediatric Hematology & Oncology,
Department of Oncology.
Chief Medical Officer,
Associate Dean for Clinical Affairs
Aga Khan University Hospital.

Stadium Road, P.O. Box 3500, Karachi 74800, Pakistan.
Cable: Akuproject, Telex: 29667 AKHMC PK, Fax: (92) 21 493-4294, 493-2095, Telephone: 493 0051

Appendix C

Permission letter from Chief Nursing Officer

Title of the Research Study

"Exploring experiences of alarm response and alarm fatigue among nurses working at ICU of a tertiary care hospital in Karachi Pakistan"

Primary Investigator: Shenila Shamsuddin
MScN student,
Aga Khan University School of Nursing,
Karachi.

Thesis Supervisor: Dr, Rubina Barolia
Associate Professor, Assistant Dean, Clinical Practices
Aga Khan University School of Nursing,
Karachi.

I, Ms. Khairunnisa Hooda, Chief Nursing Officer, at Aga Khan University, Karachi, accept your request to continue this study.

Signature

JAN 27, 2023
Date

Appendix D

Letter of invitation for the participation in the Study

Dear Participants,

My name is Shenila Shamsuddin. I am a student of Master of Science in Nursing (MSCN) at the Aga Khan University School of Nursing and Midwifery (AKUSONAM) Karachi, Pakistan. I am conducting a research study titled Exploring the Experiences of Alarm Response and Alarm Fatigue amongst nurses working at the intensive care unit of a tertiary care hospital in Karachi. Pakistan." This study is a part of the Master of Science in Nursing (MSCN) program. It will be supervised by Dr. Rubina Barolia, Associate Professor, Assistant Dean, and Clinical Practice, at Aga Khan University School of Nursing and Midwifery (AKU-SONAM), Karachi Pakistan.

I invite you to participate in my study. This qualitative study aims to explore nurses' experience of alarm response and will develop new insight into how desensitization towards alarms can be reduced. The data collection process will be conducted via non-participatory observation and semi-structured. The study will provide an opportunity for the participants to reflect upon their perceptions of alarm response and alarm fatigue. Additionally, the information provided by the participants will facilitate in exploring the experiences of ICU nurses in association with the Pakistani context.

I thank you for considering this invitation. You can show your interest in participation by contacting Ms. Shenila Shamsuddin at the Aga Khan University School of Nursing and Midwifery.

Sincerely,

Shenila Shamsuddin

Mobile Number: 0315-8330504

Email Address: Shenila.shamsuddin2@scholar.aku.edu

Appendix E

Consent Form

The Aga Khan University

Informed Consent Form

	Project Information
Project Title: Exploring experiences of alarm response and alarm fatigue among nurses working at ICU of tertiary care hospital in Karachi Pakistan	Version & Date: 2nd March 2023 Version 1
ERC Project No: 8351	Sponsor: None
Principal Investigator: Dr Rubina Barolia	Organization: AKUH
Location: Karachi, Pakistan	Phone: 03002150677
Other Investigators: Shenila Shamsuddin	Organization: AKUH
Location: Pakistan	Phone:03158330504

Title of study:

Exploring experiences of alarm response and alarm fatigue among nurses working at ICU of a tertiary care hospital in Karachi Pakistan.

Primary investigator

Dr. Rubina Barolia

Co-Investigator:

Ms. Shenila Shamsuddin

Introduction:

I am Shenila Shamsuddin student of Master of Science in Nursing (MScN) at Aga Khan University School of Nursing and Midwifery Karachi. I am conducting my research study on

the experiences of nurses toward alarm responses and alarm fatigue in the ICU at tertiary care hospital. This study is supervised by Dr. Rubina Barolia, Associate Professor, Assistant Dean, and Clinical Practice, at Aga Khan University School of Nursing and Midwifery (AKU-SONAM), Karachi Pakistan. I would like to invite you to participate in this research study.

Purpose of research study

This qualitative study aims to explore nurses' experience of alarm response and will develop new insight into how desensitization towards alarms can be reduced. The objectives of this study are to describe the type and frequency of alarms produced by cardiac monitors and the experiences of nurses about alarm fatigue in ICU setting. This study will also enable us to determine whether revision of clinical alarm policies is required to provide a patient safety environment in a hospital setting.

Procedure

The data collection process will be conducted via non-participatory observation and semi-structured interviews. To conduct observation, the researcher will be reviewing 20 camera recordings of the ICU of 3 different shifts for the alarm to sound. These observations will take place either in the morning hours or evening shifts. Through camera observation, researchers will take detailed field notes of the type and frequency of alarms, parameters set for individual patients, and the way nurses responded to and managed those alarms. The observation will serve as a tool for triangulation in our study. The second phase would be an interview, in which your experiences regarding the impact of clinical alarms would be assessed through an interview guide. If you agree to participate in this study, you will be asked to answer questions about your perception about clinical alarms and alarm fatigue which will take 30 to 45 minutes. The interview guide and your response will be in Urdu or English language in whatever language you are comfortable with. After data collection in Urdu, interviews will be translated

into English. Further, to ensure privacy interviews will be conducted in a silent space. The interview would be audio recorded.

Possible risks or benefits

There is no harm predicted to the participants in this study. There will be no financial incentives for the participants. However, the study will provide you an opportunity to reflect upon your experiences and barriers regarding in-patient clinical alarms.

Right of refusal to participate or withdraw.

You are free to choose to participate in the study. You may also withdraw at any time from the study. You also have the option not to answer any question with which you are not comfortable.

Confidentiality

We will respect your privacy. The information provided by you will remain confidential. Your name, address, and data produced during this study will be stored in a secure, locked location. Only members of the research team will have access to the data. This could include external research team members. Any records or data obtained as a result of participation in this study may be inspected by the sponsor or by AKU ERC members. Following the completion of the research study, the data will be kept if required before it is securely destroyed. Research results will be shared through journal publications and academic conferences. When the results of this study are shared, your identity will not be disclosed.

Available Sources of Information

If you have any further questions, you may contact me at 03158330504 or email me at shenila.shamsuddin2@scholar.aku.edu

Voluntary Participation:

It is your choice to take part in this study. You must give written consent if you agree to participate in this study. You may refuse to participate without any loss. You may also refuse to answer some or all the questions if you do not feel comfortable with those questions. You may also withdraw at any time from the study.

Authorization

I agree that I have read and understood this consent form by signing this form. I undertake that the importance and the methods of the research study have been explained to me and I voluntarily agree to participate in it after knowing all the terms and conditions. I understand that I will receive a copy of this form. I understand that my consent does not take away any legal rights in case of negligence or other legal faults of anyone who is involved in this study.

Printed Name of Participant: _____

Participant's Signature _____

Date: _____

Printed Name of the person who obtain the consent: _____

Signature: _____

Date: _____

Appendix F

Observation template

Observation template:

Topic: Exploring experiences of alarm response and alarm fatigue among nurses working in the ICU of a tertiary care hospital in Karachi Pakistan

Observation date and time: 18/5/2023 1100hrs- 1300 (camera recording)
30/05/2023 1000-1300 hrs

Date	Observed shift	Type of Alarm	Level of criticality	Nature of Alarm	Nurse's response to that Alarm	Time Taken to respond to Alarm
6/5/2023	Night	HR	Level 1	False Alarm (artifacts)	Assessed and conduct intervention	3minutes (180 seconds)
6/5/2023	Night	Spo2	Level 1	True Alarm	Ignored the alarm	
8/5/2023	Evening	BP	Level 2	False Alarm	Silenced the alarm	7 minutes
8/5/2023	Night	BP	Level 2	True Alarm	Ignored the Alarm	
9/5/2023	Morning	BP	Level 2	True Alarm	Silenced the Alarm	10 minutes
9/5/2023	Evening	BP	Level 2	False Alarm	Ignored the Alarm	
9/5/2023	Night	BP	Level 2	False Alarm	Assessed and conduct intervention	5 minutes
10/5/2023	Night	HR	Level 1	False Alarm (patient's HR was within limits but alarm was beeping as alarms were not set properly)	No nurse present at bedside, Alarm auto switched off	
10/5/2023	Evening	Bp	Level 2	True Alarm	Assessed and conduct intervention	3 minutes
18/05/2023	Morning	HR	Level 1	Technical Alarm	Ignore the Alarm	
18/5/2023	Evening	BP	Level 2	True alarm	Ignored the alarm	
19/05/2023	Evening	SPo2	Level 1	True Alarm	Assessed and conduct intervention	12 seconds

20/05/2023	Night	HR	Level 1	False Alarm (ECG shows asystole while patient was stable)	Assessed and silence the alarm	5 minutes (300 seconds)
21/5/2023	Morning	HR	Level 1	True Alarm	Ignored the Alarm	
22/5/2023	Evening	Spo2	Level 1	False Alarms (limits not set properly)	Silenced the Alarm	8 seconds
25/5/2023	Night	HR	Level 1	True Alarm	Ignored the Alarm	
25/5/2023	Night	Spo2	Level 1	True Alarm	Silenced the alarm	60 seconds
28/5/2023	Evening	Spo2	Level 1	Technical Alarm (probe was detatched)	Alarm was ignored	
29/05/2023	Night	HR	Level 1	False Alarm (limits not set properly)	Alarm was ignored	
29/05/2023	Night	BP	Level 2	Technical Alarm (BP cuff was loosen and was slipped down)	Ignored the Alarm	

Appendix G

Flowsheet Observation template

Actual Setting on the monitor	Recommended setting mentioned in flowsheet
HR: < 60 >120	HR: < 51 > 130
HR: < 51 > 130	HR: < 51 > 130
HR: <60 > 130	HR: < 51 > 130
BP (Systolic): <100 >160 mmhg	BP (Systolic): <90 >160 mmhg
BP (Systolic): <90 >140 mmhg	BP (Systolic): <90 >160 mmhg
BP (Systolic): <80 >170 mmhg	BP (Systolic): <90 >160 mmhg
BP (Systolic): <90 >160 mmhg	BP (Systolic): <90 >160 mmhg
BP (diastolic): < 65 >95	BP (diastolic): < 65 >95
BP (diastolic): < 60 >95	BP (diastolic): < 65 >95
BP (diastolic): < 70 >95	BP (diastolic): < 65 >95
BP (diastolic): < 65 >95	BP (diastolic): < 65 >95
Spo2 : <90 %	Spo2 : <90 %
Spo2 : <92 %	Spo2 : <90 %
Spo2 : <94 %	Spo2 : <90 %
Spo2 : <88 %	Spo2 : <90 %

Appendix H

Interview Guide.

Topic: Exploring experiences of alarm response and alarm fatigue among nurses working at the ICU of a tertiary care hospital in Karachi Pakistan.

1. In your perception what do you understand by clinical alarms?

2. So, as per your experience, how alarms are being used in the ICU?

3. So, if the alarms ring how do nurses respond to the alarm? What is the usual practice of ICU nurses in responding to alarms?

4. In your experience, are there any instances when nurses fail to respond to the alarms, and if yes what are the reasons?

5. How do you balance the need to respond promptly to clinical alarms with other competing demands and priorities in your role as an ICU nurse?

As we know there are several alarms in the ICU, and they may sometimes beep continuously causing desensitization among nurses this phenomenon is called alarm fatigue.

6. So in your experience does alarm fatigue prevail among nurses working at the ICU? Please elaborate.

7. In your experience, what do you think are the possible reasons for alarm fatigue among ICU nurses?

8. As per your perception, how important it is to address alarm fatigue among ICU nurses?

9. As per your experience what can be the strategies to reduce alarm fatigue among ICU nurses at this hospital?

10. In your experience, what factors contribute to effective alarm management and response?

Appendix I

AKUH policy of Alarm Management.

Annexure I			Standard Clinical Alarm Limits							
Clinical Device	Alarm generated	Level of Alarm	Standard Setting				Who is authorized to set alarm	When Parameters Can Be Changed	Who is authorized to Change	When Alarms Can Be Disabled
			Peadiatric	Neonate	Obs and gyne	Adult				
Ventilator	Minute Ventilation (Tot)*	Level I	<150ml/kg >300ml/kg	<100 >250 ml/kg	Twice of maximum setting*		Physician/ Respiratory Therapist	As per physician orders	Primary nursing staff or Respiratory Therapist on physician orders or physician	Only on Physician orders as for patient with withdrawl of Life Support interevention
	Respiratory Rate (Tot)	Level I	< 1 yrs: <30 >50/ min 1-2 yrs: <25 >40 / min 2-5 yrs:< 22 >35 / min 5-12 yrs:<18 >30 / min 12-18 yrs: <10-30 / min	<30 >60 / min	Half of minimum setting*					
	Peak Airway Pressure*	Level I	<1 yrs:<110 >180 beats/min 1-2 yrs:<90 >150 beats/min 2-5 yrs: <85 >140 beats/min 5-12 yrs:<80 >130 beats/min 12-18 yrs: <60>100 beats/min	>24	>40					
	Apnea Alarm	Level I	15-20 sec	15-20 sec	15-20 Sec					
	Tidal Volume (ml)*	Level I	<4-5ml/kg >8-10 ml/kg	Not Applicable						
Cardiac Monitor	HR	Level I	<1 yrs:<110 >180 beats/min 1-2 yrs:<90 >150 beats/min 2-5 yrs: <85 >140 beats/min 5-12 yrs:<80 >130 beats/min 12-18 yrs: <60>100 beats/min	<100 >200 / min	<60 >100 beats/ min	<51 >130 beats/ min	Primary Nursing Staff or Physician	As per physician orders/as per patient clinical condition	Primary nursing staff on physician orders or physician	Only on Physician orders as for patient with withdrawl of Life Support interevention
	RR	Level II	< 1 yrs: <30 >50/ min 1-2 yrs: <25 >40 / min 2-5 yrs:< 22 >35 / min 5-12 yrs:<18 >30 / min 12-18 yrs: <10-30 / min	<40 >60/ min	<08 >25 / min	<08 >30 / min				
	BP systolic	Level II	< 1 yrs:: <70 >95mmhg 1-2 yrs: <75 >100 mmhg 2-5 yrs:< 80 >110 mmhg 5-12 yrs: <90 >120 mmhg 12-18 yrs: <90 >130mmhg	*Refer to Normative BP Chart (Annexure 8.2)*	<95 >140 mmhg	<90 >160 mmhg				
	BP diastolic	Level II	N/A	*Refer to Normative BP Chart (Annexure 8.2)*	<55 >90 mmhg	<65 >95 mmhg				
	MAP	Level II	N/A	*Refer to Normative BP Chart (Annexure 8.2)*	<60 >110	<60 >110				
	SPO2	Level I	<95%	*Refer to COD Profile (Annexure 8.2)*	<95%	<90%				
	Apnea Setup	Level I	>15-20 sec							
Apnea Monitor	Delay time	Level I	>15-20 sec							