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Exploring Intensive Care Unit Nurses' Decision Making in Alarm Management

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Exploring Intensive Care Unit Nurses' Decision Making in Alarm Management

by

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A THESIS

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Abstract

Alarm fatigue, which occurs when the exposure to an increased amount of false or nonactionable alarms leads to alarm desensitization and reduced clinical response by the healthcare provider, can pose a significant risk to patient safety. With the increasing advances in technology and frequency of alarms in our healthcare system, alarm fatigue is an important and growing safety concern that needs to be addressed. Exploring alarm-related decision making is key to reducing alarm fatigue, as it is important to the development of alarm management related initiatives, education, and policies.

To examine this, I used Interpretive Description methodology to explore factors that influence Intensive Care Unit nurses' decision making regarding alarm management, specifically how they triage and respond to various alarms. This study included 12 participants, comprised of nurses with varying levels of experience, working at three different Intensive Care Units. The results of the interviews suggest that the nurses' decision making consists of three steps that capture their alarm management response: awareness, triage, and response. Based on these results, a positive alarm management culture, standardized alarm-related education, and mentorship should be evaluated to implement an effective alarm management response and reduce alarm fatigue.

Keywords: intensive care unit, intensive care unit nurses, decision making, alarm management, alarm fatigue

Preface

This thesis is original, unpublished, independent work by the author, N. Krakova. The interviews reported were covered by Ethics Certificate REB21-0202, issued by the University of Calgary Conjoint Health Ethics Board for the project “Alarm Fatigue” on December 20, 2021.

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Chapter 1: Introduction

Introduction

It is important to the development of alarm management education that there is a clear understanding of how nurses respond to alarms. In the integrative review, I found that there is a gap in understanding how nurses respond to different alarms in a critical care setting. Thus, in my study, I focused on the factors that affect Intensive Care Unit (ICU) nurses' alarm management on the unit, how they triage different alarms, and how they respond to them.

Alarm Fatigue

Alarm fatigue, which occurs when the exposure to increased amount of false or nonactionable alarms leads to alarm desensitization and reduced clinical response by the healthcare provider, can pose a significant risk to patient safety (Sendelbach & Funk, 2013). With the increasing advances in technology and frequency of alarms in our healthcare system, alarm fatigue is an important and growing safety concern that needs to be addressed (Sendelbach & Funk, 2013). An ICU is dedicated to the management of patients developing or having life-threatening organ dysfunction, with an enhanced capacity for monitoring and various methods of physiologic organ support (Marshall et al., 2017). ICU nurses communicate and coordinate various aspects of care for their patients, including: close assessments and monitoring of the patient and attached equipment; ensuring adequate functioning of ventilators, electrocardiogram (ECG) monitors, dialysis machines, specialized catheters, tubes, medication pumps, and other medical equipment; administering and titrating continuous medication infusions and other treatments; responding to emergencies; and assisting with bedside procedures (Bersten & Handy, 2019). Managing medical equipment and alarms is a critical element of nursing within the ICU.

My Research Study

Patients in critical care typically have life-threatening illnesses that require continuous monitoring, with clinical alarms that are necessary to alert the staff of changes in patients' conditions. However, increasing alarm frequency from various sources, in addition to reported high percentages of false-positive alarms, impairs the clinical validity of these alarms. This is due to high alarm sensitivity at the expense of their specificity, which contributes to alarm fatigue, overload and desensitization (Siebig et al., 2010a). As a result, the sensory overload from the exposure to numerous false and overall alarms can threaten patient safety by delaying response time, or cause clinicians to ignore, silence, or disable important alarms (Graham & Cvach, 2010). Therefore, my goal focused on factors that could contribute to alarm fatigue, in order to help reduce it. Specifically, my research study focused on exploring factors that influence ICU nurses' decision making regarding alarm management. Decision making involves the process of observation, critical thinking, problem solving, information processing, evidence-based practice, and clinical judgement, in selecting the best action or intervention to optimize a patient's health outcomes (Standing, 2010).

Research Question

My research question was: How do ICU nurses make alarm management decisions? My goal was to better understand how the nurses respond to alarms. Specifically, my goal was to understand their awareness of different alarms, and how they triage them, and how they manage and respond to them.

Methodology

I used Interpretive Description to address my research question. This methodology is open and exploratory, it enables investigation of a clinical phenomenon that includes subjective

perceptions, relies on multiple ways of knowing, allows for pattern and variance recognition, and will ideally guide clinical practice decisions (Thorne, 2013). Thorne's (2016) Interpretive Description methodology is an inductive, analytic approach, that uses informed questioning, reflective techniques, and critical examination to guide inquiry. The goal is a conceptual description that characterizes the phenomenon studied through the use of thematic patterns (Thorne et al., 2004). Interpretive Description was suitable to address my research question as my goal was to create clinically relevant knowledge, using an in-depth conceptual description and understanding of alarm management in ICU nurses.

Significance of Research Study

With technology advancements leading to increased use of alarms in the healthcare setting, it is vital to closely examine alarm fatigue as a growing patient safety concern (Sendelbach & Funk, 2013). The Emergency Care Research Institute (ECRI) included alarm-related dangers in the top 10 health technology hazards for 2019 and 2020 (ECRI, 2019; ECRI, 2020). Alarm-related events are commonly underreported in healthcare settings (The Joint Commission, 2013). Critical care patients often have life-threatening illnesses that require continuous monitoring devices, such as ventilators, ECG monitors, infusion medication pumps, feeding pumps, and dialysis machines, with alarms that are necessary to alert of rapid changes in patients' conditions. These monitoring devices were designed to assist in decision making and enhance patient safety; however, the increasing alarm frequency originating from various sources can lead to desensitization and alarm fatigue (Graham & Cvach, 2010). The observed high percentages of false or nonactionable alarms, contributed to by the monitoring devices' high sensitivity and low specificity, impairs the clinical validity of the alarms (Siebig et al., 2010b). As a result, healthcare providers may silence, disable, or adjust alarm settings beyond the

appropriate limits to reduce the exposure to overall alarms, which could delay important clinician response and timely interventions (Bridi et al., 2014). These findings emphasize that alarm fatigue in healthcare providers is a patient safety concern that needs to be addressed (Graham & Cvach, 2010). It was important to focus on ICU nurses' decision making regarding alarm management, as examining decision making is vital in ensuring high-quality clinical practice, for nurses to provide safe, quality patient care (Benner et al., 2008).

Overview of Thesis

This thesis is divided into four more chapters. In Chapter 2, an integrative review of alarm fatigue in critical care will be presented. In Chapter 3, Thorne's Interpretive Description will be examined, including how it informed this study. In Chapter 4, key themes and findings obtained through data collection and analysis will be described. The concluding chapter, Chapter 5, will include an interpretation of the results, including the strengths, limitations, and implications of this study.

Chapter 2: Literature Review

As the first element to scaffolding an Interpretive Description study, I conducted a literature review to assess the strengths and weaknesses within the knowledge of alarm fatigue and ground the research study in existing knowledge (Thorne, 2013). With limited research on strategies to address this problem, it was important to obtain a better understanding of this concept in order to inform the design and development of the research study. Further, analyzing the existing literature can help support the development of effective interventions and policies, and provide a safer healthcare environment.

I conducted an integrative review to establish a clear conceptualization of alarm fatigue, where my focus was to assess nonactionable and false alarms in critical care settings, the relationship between exposure to alarms and clinician response time, and effective interventions at reducing this safety concern. An integrative review is the broadest research review methodology, often including experimental and non-experimental research, to better review, analyze, and understand a concept (Whittemore & Knafl, 2005).

Problem Identification

The first stage of an integrative review is focused on problem identification, where I identified the issue, variables, population, and the review purpose (Whittemore & Knafl, 2005). I used the following terms to conduct the literature search: “alarm fatigue”, “alarm desensitization”, “alarm management”, “false alarm”, “physiological monitoring” “alarm”, and “telemetry monitoring”. Although alarm monitoring can occur in various acute care settings, I narrowed the literature search by focusing on this concept in critical care areas, utilizing the following terms: “critical care”, “intensive care” or “intensive care unit (ICU)”.

Literature Search

During the second stage of the literature search, I conducted a review of both nursing literature and literature of other health sciences and social disciplines, searching the following six databases: Cumulative Index to Nursing and Allied Health Literature (CINAHL), MEDLINE, PubMed, Evidence Based Medicine Reviews, EMBASE, and Google Scholar (Whittemore & Knafl, 2005). I chose these databases as they capture health and nursing literature. The literature search was limited to peer reviewed research articles and books in the English language. As alarm fatigue is a newer concept, the literature search was limited to publication date from year 2007 to 2020. The inclusion criteria were: focus on adult critical care areas, studies reporting the actionability of alarms and clinician responses, studies reporting alarm effects on staff, and studies reporting pragmatic interventions aimed at reducing alarm fatigue. The exclusion criteria were: research articles that focused on general hospital sounds and noise, use of remote monitoring, pediatric or neonatal patient care settings, and clinical areas outside of critical care. I also utilized the ancestry method approach in this stage to search for more relevant sources as referenced in key articles, by reviewing the reference lists of useful citations I found during the searches (Poirier & Behnen, 2014).

Data Evaluation

During the next stage, data evaluation, the resulting records were screened by reviewing the abstracts for the information value and methodology, and assessing the relevant content and the effect on patient safety (Whittemore & Knafl, 2005). Out of 87 records, 35 articles were selected for this literature review, which were reviewed in full to ensure they were relevant and appropriate. After a review of these articles, a final sample of 24 nursing and other health

sciences articles were selected to provide context for my study on minimizing alarm fatigue in adult critical care settings.

Data Analysis

During the fourth stage, data analysis, I organized, summarized, and analyzed data I found on alarm fatigue from the final sample of the literature search (Whittemore & Knafl, 2005). I first organized and compared primary sources by creating broader subgroups based on how the articles related to alarm fatigue (for example, focusing on causes, effects, responses, or interventions) and the methodology used (Whittemore & Knafl, 2005). Next, I extracted data from the articles to focus and organize it into a systematic framework (Whittemore & Knafl, 2005). The extracted data was compiled into a matrix to compare the primary sources on various variables and identify the commonalities and differences, including population, location, sample size, methodology, results, strengths, and weaknesses of the study (Whittemore & Knafl, 2005). With the extracted data, I then created a concept map to visually group similar variables together to help identify patterns and themes (Whittemore & Knafl, 2005). Four themes arose from my analysis during the final step, which I then elaborated on with the synthesis of the important elements in each theme (Whittemore & Knafl, 2005).

Research Findings Related to Alarm Fatigue

After conducting an integrative review to establish a clear conceptualization of alarm fatigue, in the final sample of 24 articles, the following four themes arose during data analysis: proportion of actionable alarms in critical care, response time to alarm exposure, the effect of alarm fatigue on unit staff, and effective interventions at reducing this safety concern (Whittemore & Knafl, 2005).

Proportion of Actionable Alarms in Critical Care. The proportion of actionable alarms within the critical care setting emerged as a central theme in the literature, which were explored in five articles (Bridi et al., 2014; Görge et al., 2009; Inokuchi, 2013; Siebig et al., 2010a; Siebig et al., 2010b). Only a small portion of clinical alarms in critical care were found to be relevant and actionable, as less than 18% of alarms were reported as clinically relevant and patient-related (Görge et al., 2009; Inokuchi, 2013; Siebig et al., 2010a; Siebig et al., 2010b). Furthermore, only 54% to 71% of alarms were reported as technically true, with a high portion of false alarms resulting from clinicians or patients manipulating equipment, or clinicians providing patient care (Görge et al., 2009; Siebig et al., 2010a; Siebig et al., 2010b). The four studies originated from the United States (n=1), Germany (n=2) and Japan (n=1). Between 1,214 and 11,591 different equipment alarms were described per study (Görge et al., 2009; Inokuchi, 2013; Siebig et al., 2010a; Siebig et al., 2010b). In addition, a United States study of ventricular tachycardia ECG alarms only, revealed 87% were false positives (Pelter et al., 2020). Devices reported to have a tendency to trigger the most alarms were arterial blood pressure monitors, oxygen saturation monitors, and ECG heart rate monitors (Inokuchi, 2013; Siebig et al., 2010a; Siebig et al., 2010b).

Lastly, when assessing healthcare providers who have the ability to take alarm-related action, silencing false or nonactionable alarms comprised approximately 16% of nurses' daily bedside tasks (Görge et al., 2009). Dedicating this significant amount of time per shift to address nonactionable alarms was the second most common nursing task behind changing infusion rates and administering medications for their patients (Görge et al., 2009). The increased frequency of clinically irrelevant, nonactionable and false alarms has been highlighted as a significant risk contributing to alarm desensitization, as the equipment alarms intended to

enhance patient safety may “lead to alarm fatigue, distraction and interruption of the workflow and then a false sense of security” (Bridi et al., 2014, p. 1039). This study had a smaller sample of only 426 annotated alarms over 40 hours relative to the other identified studies. Overall, these findings emphasize that alarm fatigue is a patient safety concern that needs to be addressed, as clinicians may alter disable, silence, or adjust alarm settings beyond the appropriate limits to decrease the amount of overall alarms (Bridi et al., 2014). This could delay important clinician response, or result in missed patient status changes that require clinical interventions (Bridi et al., 2014).

Response Time to Alarm Exposure. Next, the response time to alarm exposure emerged as another key theme, as the identified research studies have not only demonstrated a slower, but also an entirely absent response among healthcare professionals (Oliveira et al., 2018). In two studies that included between 76 and 103 recorded alarms, between 66% and 72% of alarms stopped sounding before a clinician responded to them, or remained without being attended to for more than 10 minutes (Oliveira et al., 2018; Pergher & Da Silva, 2014). Oliveira et al. (2018) emphasized the need for effective response to alarms by reporting that less than 26% of alarms garnered a response within less than five minutes. In contrast, in studies assessing perceptions of ICU nurses related to clinical alarms, 76 to 77% of staff believed that they were sensitive and quick to respond to alarms (Casey et al., 2018; Mirhafez et al., 2019).

Effect of Alarm Fatigue on Staff. Next, ICU nurses’ knowledge and perceptions of alarm fatigue, and their decision making in managing alarms in clinical areas arose as related central themes during the data analysis.

Clinician Perceptions of Alarm Fatigue. In multiple studies, nurses recognized that they experience excessive numbers of false or nuisance alarms (Cho et al., 2016; Mirhafez et al.,

2019; Petersen & Costanzo, 2017; Sowan et al., 2015b; Sowan et al., 2016). As such, nurses often believed that the increasing frequency of alarms disrupts patient care, reduces trust in monitoring devices, delays important clinician responses, and results in inappropriately disabling vital alarms (Casey et al., 2018; Sowan et al., 2015b). ICU nurses also believed monitoring devices are complex and inadequate in alerting them to changes in patients' status (Sowan et al., 2015b; Sowan et al., 2016). In addition, studies have highlighted a significant level of alarm fatigue among ICU nurses (Casey et al., 2018; Cho et al., 2016; Sowan et al., 2015a). Casey et al. (2018) observed a deficit in knowledge of alarm fatigue prevention, and indicated the need for further staff education. They also reported that majority of the nurses believed that frequent nonactionable alarms diminished trust in alarms, reduced their attention to the monitors, and believed that the available alarm management practices and policies were ineffective (Casey et al., 2018). Christensen et al. (2014) supported these findings by adding that this desensitization is largely associated with frequent alarms from inappropriately set monitoring limits.

Next, Honan et al. (2015) demonstrated that nurses fear the impact alarm fatigue has on patients, describing the common false alarms as an occupational hazard. Regarding education and training, multiple studies have highlighted that ICU nurses perceive a lack of policies of alarm management and training as an obstacle contributing to alarm fatigue (Mirhafez et al., 2019; Sowan et al., 2015a; Sowan et al., 2015b; Sowan, et al., 2016). The unit layout and undifferentiated alarm sources have also been emphasized as potential obstacles, as they can interfere with appropriate alarm management, recognition, and response (Sowan et al., 2015b; Sowan et al., 2016). These findings could suggest future research on assessing usability of monitoring devices and strategic planning of ICU layouts, as well as evaluation of clinician training and alarm management policies (Sowan et al., 2015b).

Decision Making in Managing Alarms. In addition to understanding ICU nurses' perspectives, understanding decision making regarding alarm management is also "imperative to the development of alarm-related policies, education and technology" (Ruppel et al., 2019, p. 3039). The factors that ICU nurses take into consideration when responding to alarms have been explored in two qualitative descriptive studies (n=16 and n=27) from North America (Ruppel et al., 2019; Wung & Schatz, 2018). Only these two studies examined the decision making behind alarm management that contributes to alarm fatigue (Ruppel et al., 2019; Wung & Schatz, 2018), offering further support to conduct this important work. Major factors that influenced the nurses' decision making included: knowledge of patient and their acuity, the alarm context, and years of ICU experience (nurses with less experience appeared to tolerate more frequent alarms) (Ruppel et al., 2019; Wung & Schatz, 2018). Wung and Schatz (2018) further added that adequacy of staffing and priority of competing tasks were also considered by ICU nurses when deciding on how to respond to an alarm.

Effective Interventions in Reducing Clinical Alarms. The last key theme that emerged explored interventions aimed at reducing alarm fatigue (Lewis & Oster, 2019; Yeh, 2019). In a study with 74 nurses, Lewis and Oster (2019) suggested implementing a "CEASE Bundle", a nurse-driven systematic guideline to help reduce alarm fatigue by improving alarm system management. CEASE is an acronym for "communication, electrodes (daily changes), appropriateness (evaluation), setup (patient customization), and education (ongoing)" (Lewis & Oster, 2019, p. 163). Utilizing the interventions outlined in this bundle, nuisance alarms decreased from 68% to 44%, leading to reduced alarm fatigue (Lewis & Oster, 2019). Next, in an interdisciplinary team approach with the aim to safely adjust and optimize alarm parameters, Yeh et al. (2019) found a 47% decrease in nonactionable parameter alarms. Overall, a gap persists in

the literature regarding interventions and strategies on reducing alarm fatigue in critical care, as the majority of the intervention studies on reducing alarms have been conducted in cardiology or ward settings.

Conclusion

I conducted an integrative review to establish a clear conceptualization of alarm fatigue, which resulted in a final sample of 24 nursing and other health sciences articles. Four themes that arose during the last stage of the integrative review were proportion of actionable alarms in critical care, response time to alarm exposure, the effect of alarm fatigue on unit staff, and effective interventions at reducing alarm fatigue (Whittemore & Knafl, 2005). Overall, there is a high incidence of alarms that contribute to alarm fatigue noted in the existing literature. Also, ICU nurses are aware that alarm fatigue is a patient safety concern. However, the body of literature relevant to decision making of ICU nurses in alarm management and effective interventions in reducing alarm fatigue is limited. Before educational initiatives or policy development can occur, a clearer understanding of how nurses make decisions in alarm management is required. Therefore, I conducted an Interpretive Description study focusing on understanding ICU nurses' decision making in alarm management.

Chapter 3: Methods

Informed by Thorne's (2016) Interpretive Description methodology, this research seeks to enhance understanding of the decision making processes and identify factors that influence nurses' customization of clinical alarms and alarm management, to reduce alarm fatigue. The aim of Thorne's (2016) Interpretive Description methodology is to extract patterns and themes using an inductive approach that uses critical examination, reflective techniques and informed questioning. Interpretive Description philosophically aligns with interpretive naturalistic orientations, acknowledging the constructed human experience while allowing for shared realities (Thorne et al., 1997).

Ontological Roots and Epistemology

Interpretive Description is ontologically situated in relativism, and epistemologically situated in constructivism (Thorne, 2016). Relativism states that there is no universal truth, where reality is a subjective experience (O'Grady, 2002). In the constructivist paradigm, knowledge is produced through an interaction between the interpreter and the interpreted, where the knowledge is constructed as opposed to discovered (Crotty, 1998). By applying a constructivist lens, such as in this methodology, the inquirer interacts with the participants to access the multiple existing views of reality (Appleton & King, 1997). Various explanations for a complex phenomenon are embraced in constructivism, as they may bring about greater understanding of the issue with diverse viewpoints (Appleton & King, 1997). Different, subjective perspectives of nurses will exist and fit within the study and their multiple realities will be studied holistically, acknowledging the value of their experiential knowledge as the source of practice insight (Thorne, 2013).

Interpretive Description is methodologically informed by five key axioms of naturalistic inquiry as outlined by Guba and Lincoln (1982). This is a paradigm of inquiry, specifically “a pattern or model for how inquiry may be conducted” (Guba & Lincoln, 1982, p. 233). The axioms of naturalistic inquiry in which Interpretive Description is informed are: (a) the nature of reality, (b) the inquirer-object relationship, (c) the nature of truth statements, (d) attribution/explanation of action, and (e) the role of values in inquiry (Guba & Lincoln, 1982).

Axiom 1 ‘the nature of reality’ conveys that there are multiple, constructed realities that are to be only studied holistically, as dissociating them would alter them significantly (Guba & Lincoln, 1982). Inquiry into the multiple realities raises more questions, and as such, prediction and control will be unlikely outcomes (Guba & Lincoln, 1982). This axiom of naturalistic inquiry is embedded in Interpretive Description, as the outcome is to generate new insights and form new inquiries, and then translate them to practice (Thorne, 2016).

Axiom 2 ‘the inquirer-object relationship’ conveys that the researcher and the objects of inquiry interact and therefore influence each other (Guba & Lincoln, 1982). This axiom is evident in interpretative description as “the knower and the known are inseparable” (Thorne et al., 2004, p. 3).

Axiom 3 ‘the nature of truth statements’ explains that the goal of the inquiry is to develop idiographic knowledge rather than generalizations, as “phenomena are neither time- nor context-free” (Guba & Lincoln, 1982, p. 238). This axiom is reflected in Interpretive Description studies as they focus on the context and time within which human experiences occur (Thorne, 2016). The inquirer is encouraged to uncover parts of an experience that arise from the context within which the experience occurred, and use it to inform practice (Thorne, 2016).

Axiom 4 ‘attribution/explanation of action’ claims that various interacting events, factors and processes can explain and shape an action (Guba & Lincoln, 1982). Guba and Lincoln (1982) further explain that the inquirer can only establish inferences about the patterns, which is best achieved holistically in the natural context. This axiom is evident in Interpretive Description as a single variable cannot adequately quantify or represent a complex phenomenon (Thorne, 2016). Therefore, fostering multiple viewpoints is more likely to lead to the probable truths, as well as encourage ongoing investigations (Thorne, 2016).

Finally, axiom 5 ‘the role of values in inquiry’ claims that the inquiry is value-bound (Guba & Lincoln, 1982). Guba and Lincoln (1982) capture the following values that influence the inquiry: (a) values of the researcher; (b) values embedded in the paradigm that guides the research; (c) values embedded in the theory, used to guide the collection, analysis, and interpretation of results; (d) fundamental values in the context, that characterize human phenomena; and (e) the values in the paradigm, theory, context, and the problem must be congruent to produce meaningful results. Guba and Lincoln’s (1982) naturalistic inquiry refers to the hallmark of qualitative research, which is for the inquirer to locate themselves in the research and discipline (Thorne, 2016). This process includes recognizing the factors that contribute to the research problem, as well as any motivations, perspectives, or biases the inquirer may have (Thorne, 2016).

Suitability for this Research

Thorne’s (2016) Interpretive Description methodology was best suited to address my research question as my goal was to create clinically relevant understanding and utilize this knowledge to enhance patient care. My overall goal was to identify how ICU nurses make alarm management decisions to help reduce alarm fatigue and enhance patient care, using this

methodology's emphasis on generation of clinically relevant knowledge (Thorne, 2016). Interpretive Description was also the most appropriate as it is a theoretically flexible and adaptable qualitative approach, with the goal of discovering recurrent patterns to understand complexities in health care (Thorne et al., 1997). This methodology also allowed me to create a deeper understanding of the subjective reality of the ICU nurses in my study (Thorne, 2016). In addition, the researcher is a valuable tool in Interpretive Description (Thorne, 2016). I utilized my technical and clinical knowledge, research background, and clinical experience to inform and frame how ICU nurses' make alarm management decisions. However, I was mindful to use reflective techniques to mitigate my insights and bias in the emerging themes.

Rigor

It was important to maintain a rigorous process in Interpretive Description study, and account for the effects of bias as the research findings and themes emerged (Thorne et al., 1997). Rigor is established through the principles of trustworthiness (Thorne et al., 1997). Trustworthiness includes elements of credibility, dependability, and conformability, which helps the researcher persuade readers of the acceptability and usefulness of the study (Lincoln & Guba, 1985). Interpretive Description requires a method of retracing the development of abstractions, “to ensure that the analytic directions are defensible” (Thorne et al., 1997, p. 175). I compiled an audit trail of my analytic process that includes a record of the steps I took in transforming the initial data into the finalized data interpretation (Appendix A). An audit trail of the data collection process can help establish dependability, which is an important factor of trustworthiness in research (Lincoln & Guba, 1985). In addition, I reviewed the data and transcribed the interviews verbatim, and checked the interviews against the transcripts multiple times to ensure accuracy of the data findings.

Interpretive Description is also informed by reflexivity, which involves laying open pre-conceptions and navigating assumptions when entering the study, and avoiding premature conclusions during emerging conceptualizations (Thorne et al., 2004). Reflexivity means “turning of the researcher lens back onto oneself to recognize and take responsibility for one’s own situatedness within the research and the effect that it may have on the setting and people being studied, questions being asked, data being collected and its interpretation” (Berger, 2013, p. 220). To help account for the influence of as much bias as possible, I kept a reflective journal during data analysis to document my reactive processes, including interpretation, rationale, or countering of any biases (Thorne et al., 1997). I included sufficient information in the reflective journal for readers to understand my analytic reasoning, and assess how well the analysis is established from the data (Thorne et al., 1997). By incorporating a reflexive account, my goal was to “describe to readers ‘what is going on’ while researching” (Koch & Harrington, 1998, p. 889). Reflexive auditing, or monitoring the influence of my values and communicating my entailment in my own research, also helps build confirmability, which is another level of trustworthiness in research (Lincoln & Guba, 1985). As a current ICU nurse, I engaged in self-critique prior to entering the study, and opened the possibility for various voices to be included in the research product (Koch & Harrington, 1998). From my eight-year experience of working as an ICU nurse, I had a presumption that alarm management practices will vary the most between novice and more experienced nurses. On multiple occasions, I witnessed more novice nurses set more narrow alarm parameters, spend more time customizing the alarms, while also tolerating more alarms, even if the alarms were nonactionable or not significant. My assumption for this observed alarm management practice in more novice nurses was the concern in missing important clinical patient changes. In contrast, I have observed more experienced nurses widen

their alarm parameters and presumably focus on the big picture when it comes to their patient. Another assumption I had is that unit staffing might also influence alarm management practices. With lower staffing levels or increasing patient assignments, I believed alarm management or customization might turn into a lower priority. Especially during the increasing ICU patient load and burden during the COVID-19 pandemic, I assumed that alarm management practices have been viewed as a low priority tasks by some ICU nurses. Overall, my reflective journal helped me explore my positioning of self as it relates to the work, as I continued to use this tool during the data collection and analysis stages (Thorne et al., 1997).

Ethical Considerations

As the study involved participation by human subjects (i.e., ICU nurses), I applied to the University of Calgary Conjoint Health Research Ethics Board (CHREB) for study approval. I received CHREB approval on December 20, 2021(Appendix B). Given that ICU nurses would be recruited through Alberta Health Services (AHS), I also received operational approval to recruit participants (Appendix C). Lastly, as a researcher for this study, I completed the Certificate of Completion of the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans Course on Research Ethics (TCPS 2: Core) on October 20, 2019 (Appendix D). This helped me adhere to a rigorous and ethical conduct, while upholding the value of respect for human dignity (Government of Canada, 2018).

Anonymity of participants was protected by removing personal identifiers from the transcripts and using pseudonyms when reporting. Any potential identifiable information was reviewed with the participant, and they were able to change, omit, or use their quote. All members of the research committee that had access to the data were aware of the responsibilities concerning participants' anonymity and completed the TCPS 2 Course on Research Ethics. I

only used a University of Calgary account (institutional platform account) when completing the interviews via a secure Zoom platform. The electronic data were both encrypted and password protected, and stored on the secure University of Calgary's OneDrive. The personal laptop used to access the secure University of Calgary storage was password protected. The document with the list of the participants' names and identifiers was also password protected and saved in a separate file on the University of Calgary's OneDrive, and only available to me. No transcription software devices were used, as I reviewed the data and transcribed the interviews myself. Data will be retained for five years as per University of Calgary Research policies from the date of project closure.

Recruitment and Sampling

I recruited participants between January and June of 2022. Participants were recruited through ICUs at three hospitals in Calgary, Alberta (Appendix E). To recruit potential participants, a letter was sent out by the unit managers to their nursing staff, and posters were placed in strategic areas on the units (Appendix F). Potential participants were directed to make contact with me via email or phone. Once contact was made, I obtained the prospective participants' contact information (name, phone/email, and how they wished to undertake the interview via phone/zoom) and arranged the interview for a mutually agreeable time.

I also used a purposive sampling technique. I recruited ICU nurses from different sites in Calgary, with varied levels of critical care experience. Initially, I looked for nurses with a minimum of six months of experience, to be able to provide detailed information about their alarm management experiences. With purposive sampling, which is the "strategic identification of key informants" (Thorne, 2016, p. 99), it was important to recruit nurses who were accustomed to working with various types of technology and alarms in an environment with

repeated background noise. Instead of data saturation, my goal was to obtain a deep understanding of the ICU nurses' realities and perspectives, while being aware of the possibility that variation in their perspectives might exist (Thorne, 2016). Using this desired outcome of Interpretive Description, I included 12 participants in my study.

Data Collection

Data collection occurred by telephone or a secure Zoom platform. First, I provided study information to prospective participants and sought verbal informed consent (Appendix G). I also obtained demographic information (Appendix H). I included demographic data such as the years of ICU nursing, their full-time/part-time/casual status, and whether they work days, nights, or both types of shifts, as these could be possible factors in alarm management (Ruppel et al., 2019; Wung & Schatz, 2018). I conducted semi-structured interviews. I audio-recorded the interviews and then transcribed the questions and participant responses verbatim. By applying a constructivist lens, my purpose was to interact with the participants to clarify and better understand the diverse existing knowledge and views behind their practices (Appleton & King, 1997). I asked the participants questions from the beginning interview guide in the outlined order, which were developed based on the current literature about alarm management and alarm fatigue in ICU (Appendix I).

These questions reflect the methodological underpinnings of this study, as I sought to construct and understand what constitutes the decision making of ICU nurses, rather than "collecting" the data (Thorne, 2016). These questions slightly evolved throughout the study, as I evaluated the need to modify the interview guide throughout the ongoing comparative collection and analysis of the data (Coyne, 1997). Specifically, instead of focusing only on the factors that affect the overall alarm management response in question four, I expanded my inquiry to better

understand how the nurses responded to alarms. My goal was to better understand how or when they hear different alarms, how they triage the alarms, and how they manage various alarms in an ICU setting. My guiding questions included inquiring about how the nurses make specific alarm-related decisions, and how they respond to different alarm-related situations. I also illustrated different alarm-related scenarios, for example regarding noticing different types and acuity of alarms at the same time, and then inquired about the decisions and actions they would perform and prioritize.

Data Analysis

I used Braun and Clarke's (2006) thematic analysis to identify themes from the interview data to illustrate the factors that affect nurses' alarm management. Thematic analysis is a "method for identifying, analyzing and reporting patterns within data" (p. 79), which can be applied to various qualitative research methods (Braun & Clarke, 2006). Thematic analysis is well suited for constructivist research approaches, such as in Interpretive Description, as it can demonstrate how a certain construct develops through the analysis of the data (Braun & Clarke, 2006). It is an appropriate analysis method when attempting to understand a set of experiences, behaviors, practices, or thoughts across a set of data (Clarke & Braun, 2016). Thematic analysis also offers an accessible and flexible approach to analyzing qualitative data, where I moved in a recursive process between the phases of the analysis. The analysis moved through: (a) familiarizing oneself with your data; (b) generating initial codes; (c) searching for themes; (d) reviewing themes; (e) defining and naming themes; and (f) producing the report (Braun & Clarke, 2006).

During the first stage of familiarization with the data, I transcribed the participants' words from the interviews verbatim into written form, and checked the transcripts against the

original audio recordings to ensure accuracy (Braun & Clarke, 2006). I then read through the entire data set at least once to further familiarize myself with the data and took notes as I searched for patterns and meanings before I began generating codes (Braun & Clarke, 2006).

Following the generation of an initial list of themes and ideas about the data, I moved to the second phase of generating initial codes (Braun & Clarke, 2006). Codes “identify a feature of the data (semantic content or latent) that appears interesting to the analyst” (Braun & Clarke, 2006, p. 88), referring to the most basic element of the information that can be assessed as it relates to the research problem. With the assistance of the supervisor, I systematically performed initial coding, where I identified the codes, corresponded them with aspects of the data, and then matched the data together within every code (Braun & Clarke, 2006). I identified data segments that began to form and repeated patterns by writing notes on the texts and using highlighters to classify potential patterns, and then cut and pasted aspects of data into a Microsoft Word document to match them together using separate files (Braun & Clarke, 2006). Aspects of data were coded and fit into various different themes (Braun & Clarke, 2006).

After I completed the initial coding process and created a list of different codes across the data set, I moved to the third phase of searching for themes (Braun & Clarke, 2006). I analyzed and interpreted the codes as I thought about their relationships, by organizing the codes into potential themes and sorting the coded aspects within each theme (Braun & Clarke, 2006). I wrote the name of each code with a relevant description on separate files and organized them into the different theme-piles, and thought about the relationship between the themes and the different levels of themes (Braun & Clarke, 2006). Braun and Clarke (2006) explain that it is acceptable to create a miscellaneous theme as some codes may not fit anywhere. At the end of

this phase, I put together a collection of potential themes and sub-themes, with all aspects of data coded within them (Braun & Clarke, 2006).

After developing a set of potential themes, I reviewed and refined them in the fourth phase of thematic analysis (Braun & Clarke, 2006). Aspects of data within the themes “should cohere together meaningfully, while there should be clear and identifiable distinctions between themes” (Braun & Clarke, 2006, p. 91). First, I reviewed the themes at the levels of the codes, by reading the organized aspects of the data for each theme and thinking about whether they form a clear and logical pattern (Braun & Clarke, 2006). If the themes did not appear to fit, I went back and considered whether the collated data extracts did or did not fit, or whether the problem is the theme itself (Braun & Clarke, 2006). Once the coded data formed a coherent pattern and was adequately captured by the themes, I moved to the second step of this phase where I assessed the validity of the themes and considered whether they “accurately reflect the meanings evident in the data set as a whole” (Braun & Clarke, 2006, p. 91). I re-read the data set to assess whether the themes made sense and fit within it, and performed additional coding that I might have missed earlier (Braun & Clarke, 2006). Braun and Clarke (2006) explain that re-coding is expected as it is an ongoing process.

I further refined the themes during the fifth phase, by identifying the data extracts that each theme captured and defining what each theme was about (Braun & Clarke, 2006). I went back to the coded data for each theme and organized them in a coherent manner, and described what appeared of interest about them (Braun & Clarke, 2006). For each theme, I wrote a detailed analysis, that included an analytic narrative and a description of how it fit into the overall story about my research question (Braun & Clarke, 2006). I also considered how the themes related to one another, and whether they contained any sub-themes (Braun & Clarke, 2006). At the end of

this phase, I had clearly defined themes, and thought about the names to give my themes in the final analysis (Braun & Clarke, 2006).

The last phase involved final analysis and the written report, where I illustrated the complex story of my data “in a way which convinces the reader of the merit and validity” in relation to my analysis (Braun & Clarke, 2006, p. 93). My goal was to provide enough detailed evidence of the themes in my data, and include coherent and logical aspects of the data that were incorporated within and across the themes (Braun & Clarke, 2006). Overall, my goal was to go beyond the description of the data with the analytic narrative to make a strong argument in relation to my research problem (Braun & Clarke, 2006). The anticipated outcome of my research study was to identify patterns across the interview data and relationships between the themes to illustrate the factors that affect nurses’ alarm management in critical care. My goal was to identify factors that influence the nurses’ decision making process and/or customization of clinical alarms, recognizing factors that could contribute to alarm fatigue.

Chapter 4: Findings

In this chapter, I describe the characteristics of the study participants and the themes that arose during data analysis. The three main themes that were highlighted that capture ICU nurses' decision making when managing alarms are: (1) their awareness, including how they hear the alarms, (2) how they triage different alarms, and (3) how they respond and prioritize different alarms. Participants are identified using pseudonyms with direct quotes to illustrate their experience and decision making regarding alarm management in ICU.

Participant Characteristics

A sample of 12 nurses was recruited for this study (Table 1). The sample comprised of nurses with varying levels of experience, ranging from six months to 20 years. With purposive sampling, which is the “strategic identification of key informants” (Thorne, 2016, p. 99), my goal was to recruit experienced nurses who were knowledgeable and skilled in working with different types of alarms and technology, in critical care environments. In doing this, I continued to sample participants until a deeper understanding of ICU nurses' perspectives regarding their alarm management was gained.

The sample was equally split between the three different age groups, with four participants aged 22 to 30 years, four participants aged 31 to 40 years, and four participants between the ages of 41 and 50 years. The majority of the participants (n=9) worked both day and night shifts (Table 1). The interviews ranged from 25 to 58 minutes in length, with a mean of 46 minutes. Additional participant characteristics are highlighted in Table 2. The interviews were undertaken in via Zoom and were audio-recorded. I then transcribed all interviews verbatim.

Table 1*Participant Characteristics*

	Participants (n=12)
Age (years)	
22-30	4
31-40	4
41-50	4
Gender	
Women	10
Men	2
ICU Experience	
6 months – less than 2 years	3
2 years – less than 5 years	1
5 years – less than 10 years	3
10 years – 20 years	5
Employee Status in ICU	
Full-time employment	6
Part-time employment	3
Casual employment	3
Shifts Worked in ICU	
Day shifts only	3
Night shifts only	0
Both day and night shifts	9
Role in ICU	
Bedside RN	7
Outreach RN	1
Nurse Clinician	2
Nurse Educator	2

Table 2*Participant Pseudonyms*

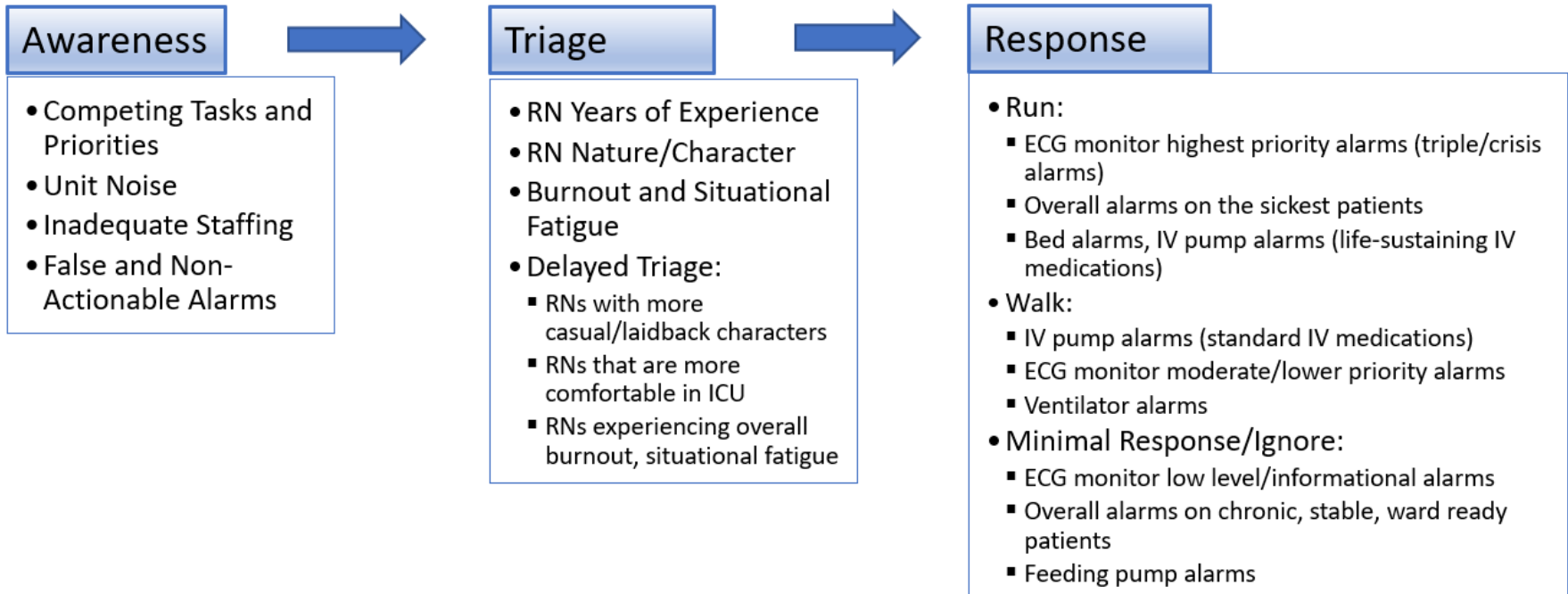
Pseudonym	ICU Experience	Role in ICU	Employment Type/Shift Type
Dorothy	6 months – less than 2 years	Bedside RN	Full-time employee, both day/night shifts
Walter	6 months – less than 2 years	Bedside RN	Casual employee, both day/night shifts
Killian	6 months – less than 2 years	Bedside RN	Casual employee, both day/night shifts
Frances	2 years – less than 5 years	Bedside RN	Full-time employee, both day/night shifts
Martha	5 years – less than 10 years	Bedside RN	Part-time employee, both day/night shifts
Clara	5 years – less than 10 years	Outreach RN	Part-time employee, both day/night shifts
Trudy	5 years – less than 10 years	Nurse Clinician	Full-time employee, both day/night shifts
Victoria	10 years – 20 years	Bedside RN	Full-time employee, both day/night shifts
Lucille	10 years – 20 years	Bedside RN	Casual employee, day shifts only
Sally	10 years – 20 years	Nurse Clinician	Full-time employee, both day/night shifts
Alice	10 years – 20 years	Nurse Educator	Full-time employee, day shifts only
Grace	10 years – 20 years	Nurse Educator	Part-time employee, day shifts only

Awareness

The first theme and first step of decision making is called “awareness”. Different environmental factors affect whether or how the nurses will hear the alarms. The factors that affect nurses' overall awareness in their response include competing tasks and priorities, busy nature of the unit, increased overall unit noise, inadequate staffing, and increased amount of false/nonactionable alarms (Figure 1).

Figure 1

Steps in Alarm Management



Competing Tasks and Priorities. Competing tasks and priorities can affect nurses' awareness in their response to alarms. As Martha explained, alarm management response depends on what priorities the nurses are dealing with at that moment; how busy they are, what care they are providing to the patient, and their interaction with the patient's family. Victoria added that her response also depends on her tasks at hand. If she is performing patient care, her awareness and response might be affected when holding on to the patient and unable to physically attend to the monitor to address the alarm in a timely manner. This can be also related to the increased census and busyness of the unit, as two participants explained:

If there is a lot of competing demands for resources. Sometimes the phones are ringing, people are asking for help, the IV (intravenous) pumps are beeping, people need medications, and so on, and sometimes people do not prioritize listening to the alarms. (Clara)

I find in our environment; it is about what is in our tasks at hand. We are probably focusing on multiple tasks, or maybe the nurse is just getting into the isolation gear and cannot address the alarm right away. (Alice)

Two participants added that the recent pandemic had an impact on the busyness and volume of patients on the unit, contributing to increased tasks that may decrease the nurses' awareness of alarm presence. Clara explained that the census used to be significantly lower prior to the pandemic. She now noticed the increased volume of patients, that she explained led to more tasks for the nurses as well as alarms present on the unit. Clara added that this impacts the nurses' awareness of alarms, as it may reduce the alarm management response when it is difficult to know which room the alarms are coming from. Clara emphasized that a delayed alarm management response is observed among nurses who are caring for more patients, which often means more alarms, and more equipment with which they must contend. Another participant agreed when she said:

When we are so busy due to the pandemic, for example with proning and unproning patients with lots of staff present in one room, and multiple alarms are going off, I think that it is more challenging to manage and respond to alarms efficiently. (Dorothy)

Unit Noise. The second factor that contributed to nurses' decreased awareness and consequent alarm management response was the overall increased noise within the unit. Sally explained that with an increasing number of patients on the unit, the overall unit noise increased as well. Trudy agreed, stating that when she goes home, she continues to hear the unit noise and beeps from alarms from the constant noise stimulation. Several other participants also expressed how the overall unit noise decreased their awareness and capacity to listen to and respond to alarms in a timely manner:

The noise level is another factor in my alarm management response. If you are not physically in the room, or beside a central monitor, and there is a lot of competing noise, you may not notice or be aware of the alarm right away, and that can delay your response to it. (Clara)

Things are ringing all the time which can desensitize you, so you are not aware of when something important actually happens. Unfortunately, we have alarms not just for monitors. We have alarms from beds, from the ventilators, from pumps, from dialysis machines... there is that constant noise in the background on the top of the equipment and the beeps and the pumps. (Alice)

Killian added how overall noise impacts his ability to hear and respond to alarms efficiently, by explaining the noise difference between a day shift and a night shift. On a day shift, there is usually more activity, ambient noise, healthcare provider rounds and lots of other events going on. He added that alarms are ever-present on both shifts, but on night shifts, when there is a lot less overall activity going on, alarms are more pronounced. Therefore, Killian has observed an increased awareness of alarms on night shifts, as well as an urgency to address the alarms, to maintain the quieter nature of the shift.

Inadequate Staffing. The next factor that can affect nurses' awareness in their alarm management response is inadequate staffing. Closely related to inadequate staffing is the

increase in the patient to nurse ratio and increasing doubled assignments, where the nurse is responsible for two ICU patients. Several participants have observed decreased awareness in the alarm management response when nurses are doubled due to inadequate staffing. Sally, a nurse clinician, has observed this delayed response when the nurses are busy in their patients' rooms, and do not have the ability to listen to the alarms of other patients that they may also be responsible for. Another nurse clinician, Trudy, added that with limited staff present on the unit, there are fewer nurses aware of the alarms, and therefore fewer nurses attending to them. A few other participants agreed (Appendix J):

I think how busy we are affects the response as well. Depending on how many staff we have, sometimes there are triple alarms going off, and if everyone is in the room except for one person, then the response is a lot slower to the alarms as well. (Walter)

If you have a two-patient assignment, and you are stuck in your room, and you hear the alarms going off, then it is a bit tricky. And if everyone else is in their rooms as well, then of course you see a delayed response. (Dorothy)

Other participants have added what a significant role the pandemic has played in decreased staffing levels or increasing the patient to nurse ratio, due to the increased number and acuity of the patients in critical care. Frances explained that due to the pandemic, she has observed an increased number of alarms that nurses need to respond to, and they try their best to be aware of all of them in order respond to them in a timely manner. Victoria added that due to how busy they have been during the pandemic, the nurses may not be able to get to all of their patients' alarms as quickly, as they might be more overall alarms. With this increased workload and increasing doubled assignments, their awareness of the alarms may be reduced, resulting in an overall slower response.

False and Nonactionable Alarms. The last factor contributing to a reduced awareness in alarm management is the increased amount of false or nonactionable alarms present in critical

care. The majority of the participants have made this observation; Trudy explains that most experienced ICU nurses know that there are countless alarms that happen every day that may not mean anything, so it is very easy to become unaware of them. Multiple nurses have emphasized the number of false alarms they experience regularly. For example, Dorothy explained that there may be a lot of artifacts noted due to sensitive or misplaced ECG leads that lead to false lethal rhythms. Clara added that sometimes a patient may frequently alarm due to artifact caused by patient movement, or an alarm due to an arrhythmia that is self-limiting. She further added that when a patient frequently alarms due to a self-limiting arrhythmia, meaning that it is not problematic, and it does not require a response, it can lead to nurses ignoring it. Clara compared it to the boy who cried wolf situation, where nurses could ignore a situation that needs to be addressed, which is quite concerning. Several participants also explained their concern with frequent false alarms (Appendix J):

I do get frustrated with certain alarms and IV pump alarms, when they are not true or ignored. When all alarms are continuously ringing all the time, it is hard to not get desensitized to them. Sometimes when they are nuisance alarms or false alarms, like upstream occlusion in IV pumps, or just overly sensitive alarms on the ECG monitor, it can be very frustrating. (Martha)

I find majority of the time the triple alarms are not real or necessary, so no one is responding to them. Overall, it makes people less responsive to them. If you have a day where the triple alarms are going on all day, because either the ECG leads are not accurate or the patient is okay, so the alarms are nonactionable, you see that slow response by the entire team. This happens day by day, and as you are on the unit more and you hear increased alarms that do not need a response... You will hear those alarms all day, and it starts to turn into the boy who cried wolf situation, and you stop paying attention to it. (Trudy)

If patient's monitor continues to ring off as artifact, or a false alarm, you will see nurses respond slower to them over time. For example, when a patient is shivering, and you have troubleshooted everything and changed the cables, it gets tiring for the ECG to ring off as artifact, and you end up silencing the alarm repeatedly and noticing it less. I get the most fatigued by alarms if the patient keeps ringing off false alarms, for example the arterial line being positional. It is frustrating when you have to keep fixing these false

alarms, when you know that they are not an actual issue or a real alarm but keep ringing.
(Victoria)

Killian also agreed with the other participants and explained that it is interesting to see how quickly nurses can normalize and adapt to alarms. For example, when taking care of a sick patient that frequently alarms, Killian has noticed that some nurses can be quick to silence all alarms without fully assessing them once they feel that they have a good grasp of the patient and the patient's condition, assuming that they will hear similar alarms throughout the day.

Lastly, Killian added that with increased and sicker patients during the pandemic, there have been an increased number of alarms leading to greater alarm fatigue present in ICU. During the pandemic, he has observed decreased response time overall and a less obvious stress response that should normally occur with alarms in ICU. Frances agreed and noted that she has also observed more alarm fatigue lately, due to decreased patient movement in the hospitals during the pandemic. With slower patient movement, Frances has noticed more awake and stable patients, as well as ward patients that would not normally stay long in the ICU. She explained how awake and frequently moving patients still attached to ECG monitor created extra false alarms and artifact, leading to more alarm fatigue among nursing staff.

Triage

Next, nurses triaged their alarm management response and this activity varied based on their experience, nature/character, and burnout and situational fatigue. The quicker response is observed in more experienced nurses, as they are more proficient in managing alarms and have overall greater awareness of the unit and admitted patients. Alternatively, delayed triage in alarm response is associated with nurses with more laidback or casual personalities, nurses that are more comfortable in intensive care and used to hearing frequent false alarms, and nurses

experiencing overall burnout, situational fatigue, or working busier and longer stretches of shifts with minimal breaks.

Nurse Experience. The first factor that affects how nurses triage alarms in their decision making are their years of ICU experience. Trudy explained that it takes time in critical care and more experience to be able to better manage alarms. Regarding expert and more experienced nurses, several participants stated that alarm management is also quicker and more proficient due to their awareness of the unit (Appendix J).

You can see more experienced nurses manage their alarms better as they have better time management and overall skills and can also help answer other patients' alarms. As a new nurse, I think it's harder to manage everything yourself and manage your own alarms at first, and then slowly become aware of other things and alarms that are happening on the unit. It comes with more experience to be able to be aware of things that are going on outside of your patients' room and out of your assignment for the day. This plays a factor in knowing where to pay more attention and whose alarms will need to be responded to faster either because they are busy or just not as experienced on the unit. (Martha)

The expert nurses are on top of the alarms, managing them, silencing them, and adjusting them. Whereas the more junior staff and grad nurses do not seem to respond as quickly. They do respond to triple beep alarms, but it takes them time to get into the room and adjust them. (Alice)

In contrast, few participants pointed out that while less experienced or junior nurses may take longer to address the alarms, they attend to the patient quickly as they are often in a state of hyper-awareness on the unit. Sally explained that because novice nurses often have a heightened sense for their patient's alarms, they want to fix whatever is alarming. However, sometimes it may take them longer to figure it out or troubleshoot as they focus on the patient first. Sally compared this to more experienced nurses, who will generally silence the alarms first as they know what is going on with their patients. Lucille agreed as she has also observed more novice nurses take a little bit longer to silence the alarms, as they focus on the patient, the required help, and the appropriate interventions in that situation. Killian also agreed with these observations

and pointed out that as a newer nurse, he always tries to address alarms quickly and efficiently.

However, the patient takes priority over the alarms:

In terms of newer staff, which I would call myself one as well, you just do not have as much experience. You are also maybe in a state of hyper-awareness, so you are always thinking of what could go wrong. Any alarm makes you think about what is going on and what do I need to look at. I think more experienced nurses know what is worth paying attention to and are less worried about alarms. In my own practice, I generally will only leave the alarm on as a signal to the unit that I might need extra help. Overall, I think it is a good idea to address the patient first, at the end of the day, our job is patient safety, and if we push alarms to the secondary, I think that is quite alright. (Killian)

Nurse Character. Next, nurses will triage their alarm management response depending on their character or personality. Overall, several participants stated that the personality of the primary nurse could be a factor in alarm management, as some nurses can be quick to brush off assistance even with crisis alarms, or they can be anxious even with low-level alarms. Sally added that some nurses have a hyper-awareness of alarms and will prioritize them. These nurses have been observed to walk from the opposite side of the unit to address and silence an alarm for another primary nurse. Lucille agreed by explaining that when it comes to the alarms of other patients, she notices that some nurses will respond to all the patients' alarms in their area, while other nurses may take on a "that is not my problem" kind of attitude. Several participants also illustrated the difference in response related to the nurses' nature (Appendix J):

When it comes to the nature of the nurses, you can count on some to respond to alarms a lot quicker than others. Some nurses are more of a team player and will help other patients and respond to their alarms. However other nurses, if their patients' alarms are not ringing, they will have other things to do in their free time besides listening to overall alarms on the unit. Sometimes it is the not my alarm not my problem attitude, or the physical distance of another alarm that will cause them to ignore that alarm. (Martha)

I would say a big factor is professional practice, some people just do not seem to hear them... In that professional practice umbrella, you also see patterns created with certain nurses and their nature. No matter how many times you ask them if they are okay, or no matter how much you educate them about alarm management, the lack of response will still happen with certain individuals. (Trudy)

In addition to the nurses' characters, Walter also added that comfortability is another factor related to how nurses triage alarms. Walter has noticed that the more comfortable nurses are on the unit, the less alarmed they are by alarms in general, including crisis alarms. He explained that when the nurses are used to hearing frequent alarms that do not mean anything for them, or do not require a response, then they are not as likely to respond to them quickly. Nurses' comfort level also influences how they set their alarm parameters at the onset of their shift. Frances explained:

You will also see individual nurses and their comfort level and familiarity with the patients that will also affect the response. For example, if a patient is new to me, and I get the sense that they are a little bit unstable or sicker, I will set the parameters tighter. In terms of setting the alarms to a certain number below or above the patient's baseline, this is completely up to the nurses' discretion. It is up to the patient's baseline and the nurses' comfort level as to how far from the patient's baseline they want to set the alarm above or below that number. (Frances)

Burnout and Situational Fatigue. Lastly, overall burnout and situational fatigue might also affect how nurses triage their alarm management response. As Martha explained, overall increased burnout contributes to a slower response among the nursing staff. Sally agreed by expressing that increasing burnout has led to the disappearance of that "give a darn factor" in several nurses, who may not care about the moderate to lower priority or informational alarms. Lucille agreed by explaining that reduced work satisfaction and increased burnout have diminished the nurses' capacity to respond to overall patient alarms present on the unit. She further added that their alarm management response becomes more focused on their patient, as it becomes difficult to acknowledge or help answer other patients' alarms, as they routinely would do.

Related to increasing burnout, Trudy explained that when there are nurses on a shift that are experiencing situational fatigue or have had difficult or sick patient assignments lately, they

will have a reduced alarm response. Trudy has also observed this fatigue to contribute to a lack of response among nurses, as she explained that sometimes “the alarms just do not seem to be heard”. Martha agreed, by explaining her reduced awareness of alarms when physically tired:

I find that how I am feeling is a big factor, for example, some nights I come onto a shift, and I am so tired that I only have the capacity to manage my own alarms. It is exhausting when you are at that heightened alert all the time, having to listen and be quick to respond to everything on the unit. Fatigue might slow down or block my response. If I am physically tired, I will maybe wait a little bit before going down the hall to respond to a low priority alarm and see if someone closer to the room responds to it first. I find that I do not mean to block it out or ignore it for a bit, but if I am really tired and sitting in front of my patient's room, and they are all sorted, sometimes I will block out the extra noise so I can concentrate on the task at hand. (Martha)

Lucille agreed with the other participants, adding that the number of hours that nurses work is also a factor in their alarm management response. As a nurse that works on a casual basis, she has witnessed how tired her colleagues can get working full-time hours. Lucille explained that when she sees full-time nurses that have not had appropriate breaks during their long stretch of shifts, they can only manage their patient's alarms but cannot respond to other alarms on the unit. Overall, Lucille added that fatigue is a multifaceted issue related to increasing burnout, current shift status, events of previous shifts, missed breaks, working in a pandemic, and personal life factors, all of which contribute to a slower triage and response in alarm management in the ICU.

Response

In the last step of the decision making, ICU nurses incorporate multiple factors when considering how quickly to respond to an alarm or whether to respond at all. Overall, ICU nurses respond to triple alarms on the ECG monitor, overall alarms on the more acute patients, bed alarms, and IV pump alarms infusing life-sustaining medications in the most urgent manner. Triple alarms are high-priority physiological alarms on an ECG patient monitor that require an

immediate response (GE Healthcare, 2013). These are often called triple alarms by the participants based on the sound they make and are displayed red in colour. It is also important to note that the overall alarms on ECG patient monitors include medium-priority and low-priority alarms, along with triple or high-priority alarms. Medium-priority alarms are designed to require a prompt response, while low-priority alarms require awareness of the condition change (GE Healthcare, 2013). Next, ICU nurses respond to IV pump alarms infusing standard medications, moderate/lower priority alarms on the ECG monitor, and ventilator alarms in a medium, walking manner. Lastly, ICU nurses display minimal response or a lack of response to low-level/information ECG alarms, overall alarms on chronic and ward ready patients, and feeding pump alarms.

Running Response. To start with, response time in alarm management varies greatly on the type of alarm, and the severity of the alarm. The majority of the participants agreed that nurses respond to triple alarms, or crisis alarms, on the ECG monitor in the most urgent manner. As Martha and Walter explained, triple alarms get their first and instant attention. Clara, Sally, and Grace added that with triple alarms, they often observe nurses drop the tasks they are working on to attend to the alarm and make sure that the patient is okay. Victoria has explained that during a crisis alarm, her goal is to make sure the patient is okay and silence the alarms if it is false or an artifact. After attending to the patient, the nurses then verbalize if they are okay, or if they need help from the healthcare team. Trudy also illustrated the importance of an urgent response to a crisis alarm:

My priority will always be triple alarms on the ECG monitor, because those are your lethal alarms. If a patient is in ventricular fibrillation, ventricular tachycardia, asystole, or another lethal alarm, I am always running to those first to check on them. Unless of course, someone yells that they are okay. (Trudy)

Trudy further explains that sometimes the nurses will keep the crisis alarm ongoing if they cannot figure out what is going on with the patient or the reason behind the alarm, or are unsure if they need help. In all other situations, most participants agreed that they attend to both the patient and crisis alarm promptly. Lastly, Victoria stated that even though there are many false or artifact crisis alarms present in an ICU, she has witnessed less alarm fatigue to high-priority ECG alarms, compared to the other medium, low-priority ECG alarms, or alarms originating from other equipment.

Next, nurses display an urgent response when attending to overall alarms on the sickest patients, due to an increased perceived severity or threat to those patients. Sally explained that if they know a specific ICU patient is very acute or sick, they will respond to their alarms in an urgent manner. Martha agreed and stated that most nurses will be quick to respond to an alarm on an unstable or acute patient, to quickly validate the alarm and assess the patient. In general, Trudy explained that when nurses are aware that they are providing care for an acute patient, they will prepare themselves to be “more on the ball in general,” which includes a quicker alarm management response. Caring for an acute patient can also influence the nurses’ alarm management strategy. Frances explained that nurses will often set the alarms tighter during their safety check assessments when providing care for a sick patient.

Nurses also respond urgently to bed alarms, as they are not set commonly in a critical care setting. Martha and Killian explained this urgent response by emphasizing that potential patient falls, especially if there are multiple cables, IVs, or other equipment attachments, are a significant safety issue. Trudy further stated that bed alarms belong to the highest priority of the alarm management response, as bed alarms are seldom utilized unless there is a potential patient

safety risk. Therefore, when a bed alarm rings, there is a high chance that a patient is trying to get out of their bed that cannot mobilize independently or safely.

Lastly, urgency in responding to IV pump alarms is observed among nurses, however, the response can vary depending on the type of IV medication infusion. Overall, Killian and Frances agree that IV pumps infusing vasopressors, inotropes, or other life-saving medications, warrant an urgent alarm management response from nurses.

Walking Response. Next, ICU nurses respond to IV pumps, moderate/lower priority alarms on the ECG monitor, and ventilator alarms in a medium, walking manner. As discussed, alarm management response regarding IV pumps depends on the nature of the medications infusing. While inotropes and vasopressors warrant an urgent response among most nurses, they will show a medium, walking response to attend to IV pumps infusing standard medications. Martha explained that IV pumps get her medium, walking response, depending on what is going on with the patient, and whether it is a secondary IV medication flush or a more important continuous IV infusion that is causing the IV pump alarm. Trudy agreed, explaining that after responding to ECG crisis alarms and bed alarms, the next alarm that would be attended to would be one originating from IV pumps. She further explained that while she believes IV pumps should receive a more urgent response, they belong in the medium category for many nurses:

I would say this is something that we probably do not deal with as quickly as we should as most people do not run or quickly address the IV pump alarms, especially with the amount of isolation on the unit too... You also cannot easily hear in which room the IV pumps are ringing, so you can spend a long time walking around the unit to see which room the IV pump beeping is coming from. (Trudy)

Along with IV pumps infusing standard medications, a medium response is also observed among nurses in moderate and lower-priority ECG alarms. Martha stated that other ECG monitor alarms, not triple alarms, will get her medium, walking response. Few participants agreed and

explained that they do not run the moderate or lower caution alarms, but still assess their patients in a timely manner:

A moderate or lower priority alarm still needs to be looked at, but if I had two alarms going off at the same time, I would have to check the high-priority alarm first and then the lower priority alarm. (Lucille)

If it is a caution alarm, I do not see nurses running, but I do see people walking to the central monitor to see who is ringing and what is going on. If it keeps ringing, usually someone will walk over to the patient room to check if everything is okay. (Dorothy)

Overall, Victoria agreed with these participants and explained there are other ECG monitor alarms that are still important but less urgent, that nurses acknowledge and assess if they need to act on them to ensure patient safety.

Lastly, ventilator alarms will also elicit a medium, walking response among nurses, as the response is a shared responsibility with respiratory therapists. As Killian explained, when considering the overarching factors of the ABCs (airway, breathing, circulation), ventilator alarms are important in terms of relating to the airway. However, due to respiratory therapists' role in responding to the ventilators as well, these alarms can be often in the medium category for many nurses. Trudy further explained:

When it comes to ventilator alarms, I rely pretty heavily on respiratory therapists to respond to them. I am pretty good now at identifying to see what the problem is and if I can fix it or if I need a respiratory therapist to troubleshoot, so sometimes I will leave the alarm ringing so I can get a respiratory therapist to come help. (Trudy)

Minimal Response. Lastly, nurses display minimal response or a lack of response to low-priority and information ECG alarms, feeding pumps alarms, and overall alarms on chronic patients. Few participants have noted that informational or low-level alarms can be ignored in ICU. Victoria explained that when the informational alarm goes off, she sees nurses not responding to the alarm very quickly and sees them ring for a while. She added that “those alarms can be ignored by some nurses”. Clara agreed by stating that for “low-level alarms, like

low oxygen saturation or high or low respiratory rate, or even apneic rate depending on how it is set, those can be ignored”. Grace included that low-level alarms can include an oxygen probe taken off, high or low respiratory rate, or cardiac ectopy, depending on how they are set in the ECG monitor. Nurses can set most of the alarm parameters to different priorities, such as moderate, low, or informational, which will produce different sounds. The high-priority alarms, or crisis alarms, cannot be altered in the ECG monitors and will always produce an urgent sound with a red light. Grace explained that nurses do not respond to low-priority or information alarms as quickly as they should be, which can further lead to “more annoyance and more complacency” among nurses and contribute to alarm fatigue.

Next, nurses display a slower alarm management response when taking care of more stable ICU patients, or patients that are ward ready and waiting for a transfer. Trudy explained that some nurses may “let their guard down and pay less attention to sub-acute or chronic patients” even though they are still acutely unwell from anyone else's definition outside of a critical care setting. Killian further agreed, adding that more stable and awake patients’ alarms do not get acknowledged in a timely manner:

In terms of alarms that do not get acknowledged quickly, I see it on the unit in patients that are more awake, for example in patients who constantly take off their oxygen saturation probe. That alarm would be not as urgently responded to, and it would be easy to not acknowledge that. That alarm is still important, but I have observed this on the unit I suppose. I would also say the same about more chronic and stable patients, as I see that some nurses may pay less attention to their alarms. (Killian)

Sally added that if there are multiple similar alarms present on an acute patient and a more stable patient, the response time will be considerably slower to the more stable or ward ready patient.

Killian agreed with Sally and explained that the slower alarm management response on a more stable patient may also be due to the patient being awake, regularly moving around and setting off multiple false alarms, which may also further decrease the overall response time over time.

Lastly, multiple participants have viewed alarms originating from feeding tube pumps as low priority, contributing to a slower alarm management response. For example, Lucille explained that when deciding whether to respond to an ECG alarm, IV pump alarm or a feeding pump alarm ringing at the same time, most nurses would respond to the feeding pump last, in a slower manner. Martha agreed, by explaining that the feeding pump alarms are viewed as a lower priority for nurses:

At the bottom of my list, a feeding pump will get a slow response, as it is a low priority for me. It does depend on whether my patient is getting fed through a salem sump feeding tube or a silastic feeding tube, as I might respond to a silastic tube a little bit quicker as I might be worried about it getting clogged sooner. (Martha)

Conclusion

As alarm management is an important nursing responsibility in an ICU, understanding decision making behind alarm management is important to the development of more effective strategies on alarm management, and reducing alarm fatigue. Prior to integrating various factors into consideration when deciding how quickly to respond to different alarms, different environmental and unit factors affect whether or how the nurses will hear the alarms. These factors that affect nurses' overall awareness include competing tasks/priorities, the busy nature of the unit, increased overall unit noise, inadequate staffing, and increased amount of false/nonactionable alarms.

Next, nurses will triage their alarm management response depending on their experience, nature/character, and burnout and situational fatigue. Faster triage is observed in more experienced nurses, as they are more proficient in managing alarms and have overall greater awareness of the unit and admitted patients. Alternatively, delayed triage in alarm response is associated with nurses with more laidback or casual personalities, nurses that are more comfortable in intensive care and used to hearing frequent false alarms, and nurses experiencing

overall burnout, situational fatigue, or working busier and longer stretches of shifts with minimal breaks.

In the last step of the alarm management process, ICU nurses incorporate multiple factors when considering how quickly to respond to an alarm, or even whether to respond at all. ICU nurses respond to triple alarms on the ECG monitor, overall alarms on the more acute patients, bed alarms, and IV pump alarms infusing life-sustaining medications in the most urgent manner. Next, ICU nurses respond to moderate/lower priority alarms on the ECG monitor, IV pumps infusing standard medications, and ventilator alarms in a medium, walking manner. Lastly, ICU nurses display minimal response or a lack of response to low-level/information ECG alarms, overall alarms on chronic and ward ready patients, and feeding pump alarms.

Chapter 5: Discussion and Conclusion

Interpretation of Findings

Physiologic monitoring is a central element of nursing in critical care. In this study, I explored how ICU nurses make alarm management decisions, specifically how they triage and respond to various alarms. Overall, the ICU nurse participants integrated multiple factors when deciding how or even when to respond to different alarms present on the unit. Nurses did not assess or judge a specific alarm in isolation when deciding how to respond to it. Instead, the nurses' decision making consisted of three steps that captured their alarm management response: awareness, triage, and response. The factors that affected their awareness of different alarms included competing tasks and priorities, increased overall unit noise, inadequate staffing, and increased amount of false or nonactionable alarms. Next, their experience, character, level of burnout, and situational fatigue were integrated as they triaged in the second step of their alarm management response. Lastly, the nurses incorporated multiple factors in how they prioritized and responded to the alarms, including the type and severity of the alarm, the equipment causing the alarm, as well as the type of ICU patient the alarm originated from. This study confirms previous findings regarding factors affecting alarm management but also extends on the knowledge by describing the three steps of alarm management response. It identifies the decision making of ICU nurses, related to the awareness, triage, and response in alarm management.

Awareness

Multiple competing priorities and responsibilities can limit the nurses' awareness of alarms that are present in an ICU. When nurses are too busy completing other important tasks, they are often unable to hear or respond appropriately to alarms. This barrier to timely alarm management is closely connected to the nature of the unit. As several participants explained, the

increasing workload contributing to the unit's busy nature can be due to inadequate staffing or the conditions of working during a pandemic. When engaged in several simultaneous important tasks or taking care of multiple ICU patients during a shift, nurses can display a slower alarm management response. These findings were corroborated by Hyman and Johnson (2008) who analyzed various events linked to alarms' failure to generate appropriate responses, who identified that inadequate staffing and an excess of simultaneous or near-simultaneous events contributed to inadequate alarm responses. Adequate staffing has important implications for enhancing patient safety when the nurses have the capacity to respond to alarms promptly (Hyman & Johnson, 2008). With a higher workload contributing to several important competing demands, adequate staffing should be evaluated to ensure nurses have an opportunity to implement an effective alarm management response.

Next, two other factors that affected the nurses' awareness of different alarms in their alarm management response included the overall unit noise, and the increased frequency of false, nonactionable or non-clinically relevant alarms. With excessive alarms present in an ICU, nurses may normalize the alarm sounds and trivialize their alarm management response. Alarms are an important part of a critical care environment, designed to generate a stress response. However, most of the participants described that they were less likely to be aware of or concerned with managing alarms if the ICU was already noisy, with prevalent alarm fatigue among the nurses. Establishing or reinforcing a positive alarm management culture may be useful in encouraging nurses to actively participate in appropriately customizing and responding to alarms, to help decrease the amount of overall noise and false alarms. With a positive alarm culture in ICU, nurses would be better supported in creating a lower tolerance for nonactionable or non-clinically relevant alarms present on the unit.

Along with a change in the alarm management culture, integrating alarm-related education may be valuable for nurses beginning their practice in critical care. Development of education focused on general alarm management skills, alarm safety, and alarm customization practices may help nurses improve the usability of different complex alarm devices and decrease unnecessary alarms and noise. Multiple participants stated that they had little or no formal training on ECG monitors and increased their knowledge of alarm management during their orientation shifts. However, alarm management training based on the knowledge and experience of the preceptors may result in inconsistent use of different monitoring equipment. Multiple participants felt that formal training may help them manage alarms more effectively and help reduce the number of alarms present in the unit. The Joint Commission incorporated education of staff about the purpose and functioning of alarm equipment and systems in their National Patient Safety Goals for 2022, as improperly managed alarms can compromise patient safety (The Joint Commission, 2022). It is important for hospitals to have a systematic and standardized approach to contribute to safer alarm management. This approach may be customized for specific clinical areas, for staff to receive training on the proper operation of alarms that they are responsible for (The Joint Commission, 2022). However, standard one-time education focused on alarms and cardiac monitor use may not be enough to improve alarm safety and usability, and decrease unnecessary nuisance alarms (Sowan et al., 2016). This suggests the need for recurring alarm-related training, as well as research on the value of training implemented during the initial orientation and during ongoing professional development. In addition, this suggests a need for further research on standardized training and strategies on improving the safety of clinical alarm systems, as a gap persists in the literature regarding interventions and strategies on reducing alarm fatigue in ICUs. As most of the intervention studies on reducing alarms have been focused

in cardiology or ward settings, future studies should focus on systematic alarm-related training that enhances nurse-alarm interactions and improves alarm system safety.

Lastly, to help effectively deliver alarm-related training, a train-the-trainer program may help support broader implementation of alarm management (Poitras et al., 2021). It is important to identify effective ways to translate knowledge in clinical settings particularly with the growing concern regarding limited resources, and healthcare providers already communicate obtained knowledge with other healthcare professionals (Poitras et al., 2021). They act as trainers, as they teach other healthcare professionals, or trainees, to improve their knowledge and skills (Ramberg & Wasserman, 2004). Train-the-trainer programs are efficient in supporting trainers in training, and outcomes relevant to competence, knowledge, and behavior (Poitras et al., 2021). As a result, a train-the-trainer program can help nurse leaders facilitate alarm-related knowledge, assist with alarm management skills acquisition, and support the trainees' learning and behavior with the goals of improving alarm safety (Poitras et al., 2021).

Triage

In the next step of the nurses' alarm management decision making, their experience, character, burnout, and situational fatigue affect their triage of alarms in the ICU. Experienced nurses are more proficient in managing alarms. They have a greater awareness of their patient status and the overall critical care unit, contributing to a quicker triage in their alarm management response. On the other hand, delayed triage is seen in nurses newer to ICU, nurses with more laidback personalities, nurses accustomed to hearing frequent false alarms, and nurses experiencing situational fatigue and overall burnout.

Experienced nurses' proficiency in triage of their alarm management is consistent with Benner's (1984) stages of clinical competence, where expert nurses have an intuitive grasp of

their patient's status based on their experience and clinical knowledge. More experienced nurses were quick to silence and manage their alarms, as they were already aware of patient changes without relying on the alarms. Triage in alarm management can be complex and dynamic; however, expert nurses are aware of the big picture of their patients and other activities of the unit and can facilitate care simultaneously on multiple levels within changing environments (Benner, 1984). On the other hand, more novice nurses displayed delayed triage and tolerated more alarms to maintain awareness of their patients, which also aligned with Benner's (1984) work on clinical expertise. Novice nurses in a specialty area begin to comprehend complex situations but feel overwhelmed trying to identify relevant information and begin to recognize clinical changes without the experience or knowledge of how to manage them (Benner et al., 1996). Less experienced nurses may take longer to address alarms as it may take them longer to figure out the situation and identify the relevant elements behind the alarm (Benner et al., 1996). Several participants explained that novice nurses often have a heightened sense to their patient's alarms but can leave them ringing as they focus on the patient, the required help, and appropriate interventions first.

Mentorship is crucial to foster growth and development of novice nurses in a critical care setting, which in turn contributes to high-quality nursing care (Race & Skees, 2010). A mentor helps their mentee improve professional performance by guiding them through their strengths and weaknesses, establishing goals and evaluating their progress, and providing them with appropriate resources to achieve their goals (Race & Skees, 2010). Whether it is a formal or informal mentorship, a good mentor can help enhance a nurse's career development, helping them during the transition to an experienced nurse (Race & Skees, 2010). As such, mentorship should be strongly considered as experienced nurses can utilize their refined alarm management

practices helping mentor novice ICU nurses, to improve their alarm-related practices and ultimately patient outcomes.

Next, delayed triage is associated with nurses with more laidback personalities, nurses who are more comfortable working in critical care, and are used to hearing frequent, false alarms. This finding is consistent with a study examining personality traits that contribute to indicators of alarm fatigue (Claudio et al., 2021), as personality factors may influence alarm management in ICU nurses. The study used the Big Five Personality Model to assess personality traits, where the traits of neuroticism, conscientiousness, and agreeableness were associated with indicators of alarm fatigue (Claudio et al., 2021). A higher level of neuroticism was linked to increased indicators of alarm fatigue due to a higher susceptibility of anxiety and irritability (Claudio et al., 2021). Conscientiousness resulted in decreased indicators of alarm fatigue, as it is associated with good impulse control and lower levels of apathy and distrust (Claudio et al., 2021). Agreeableness was associated with increased indicators of alarm fatigue, as it represents increased alarm responsiveness (even from a distance) and prioritizing numerous alarms, which can lead to increased stress of responding to multiple alarms (Claudio et al., 2021). The ideal personality for a healthcare professional working in ICU would display “lower susceptibility to anxiety, higher levels of competitiveness, assertiveness, and proactiveness, with good impulse control, goal-directed behaviors, and high intellectual curiosity with high independence of judgment” (Claudio et al., 2021, p. 8). This suggests the need for assessing the personality traits of ICU nurses to increase their awareness of how their individualities can affect their alarm management and behaviour, to apply strategies for reducing alarm fatigue (Kubiszyn et al., 2000).

Response

In the last step in alarm management, nurses integrated multiple factors in prioritizing and responding to the alarms, including the type and severity of the alarm, the equipment causing the alarm, as well as the stability of the patient the alarm originated from. The influence of critical care experience and knowledge of different alarms in nurses' alarm management response aligns with a study by Guillaume (2011), as monitoring alarms are categorized as abstract alarms. This means that the urgency to respond to them is learned and not direct (Guillaume, 2011). When it comes to the type and severity of an alarm, the nurse acquires the meaning of the alarm through experience to respond to it accordingly (Guillaume, 2011). The mental depiction is built through learning, as alarm sounds are associated to a specific equipment or origin, and to its urgency (Guillaume, 2011). This learning allows for quicker and more appropriate alarm management responses among nurses. This suggests the need to incorporate training on distinguishing sounds originating from different equipment and different monitoring alarm types and severity, to optimize nurses' alarm management responses. This is supported by Cho et al. (2016), as they found that nurses understand the need to differentiate between different origins and severity of alarms in their alarm management strategy.

Recent Studies

Since the conception of this study, a study focused on how ICU nurses respond to clinical alarms to improve patient safety has been published (Ramlaul et al., 2021). A descriptive, non-experimental design was used with a sample of 91 nurses. A structured questionnaire was used to collect data (Ramlaul et al., 2021). The majority of the participants agreed that nuisance alarms were a factor in alarm management, contributing to a delayed response (Ramlaul et al., 2021). The risk of desensitization from the increased frequency of alarms originating from different

equipment can negatively impact patient care and safety (Ramlaul et al., 2021). The majority of the ICU nurses agreed that nuisance alarms, meaning false or nonactionable alarms, contributed to a reduced awareness in their alarm management. Several ICU nurses emphasized the number of false alarms they experience regularly, possibly caused by sensitive or misplaced ECG leads, or patient movement contributing to artifact. Few nurses also explained that nuisance alarms could be caused by self-limiting arrhythmias, meaning that they do not require a response. This further supports the need for establishing a positive alarm management culture, to encourage ICU nurses to appropriately customize and respond to alarms and decrease the amount of nonactionable, false, or overall alarms.

Strengths and Limitations of the Study

This study had several notable strengths. First, a strength of the study was the mixed representation of different nursing roles in the ICU, including bedside nurses, outreach nurses, nurse clinicians and nurse educators. In addition, while years of clinical experience may not fully reflect the nurses' ICU competency, the study had a diverse representation of different clinical experience levels. The participants' experience level varied from one year to 16 years of clinical ICU experience.

There were also some limitations. Though a hallmark of qualitative research, the sample size was small which limits the generalizability of the findings. However, the participants were gleaned from three different ICUs across the city.

Recommendations

Standardized, formal alarm-related education and training may be useful for novice ICU nurses to enhance their alarm management skills, customization, and overall alarm safety in the ICU (The Joint Commission, 2022). However, recurring alarm-related education and training

may be needed to improve alarm safety and usability across experienced nurses (Sowan et al., 2016). Further, more research on standardized training occurring throughout ICU nurses' specialist training and strategies on improving the safety of clinical alarm systems should be pursued. Incorporating education focused on distinguishing alarm sounds from different monitoring equipment should also be considered to optimize alarm management responses, as the differentiation and meaning behind different alarms is a learned skill (Guillaume, 2011). Regarding education recommendations, a train-the-trainer program may also be valuable in supporting broader implementation of alarm management and help nursing leaders facilitate alarm-related knowledge to help reduce alarm fatigue (Poitras et al., 2021). Next, establishment of a positive alarm management culture may be valuable in engaging nursing in appropriate response to alarms, to decrease the number of overall alarms and create a lower tolerance for nonactionable alarms. In addition to alarm management champions creating a positive unit culture, they can act as mentors to foster the growth of novice ICU nurses to help them improve their alarm-related practices and contribute to a high-quality nursing care (Race & Skees, 2010).

Conclusion

The findings of this study illustrate the steps in alarm management, identifying the decision making of ICU nurses. As decision making processes are vital for developing appropriate policies, training, and education (Ruppel et al., 2019), this work may lay a foundation for the development of new knowledge, educational strategies, practice guidelines or tools that support alarm management, to minimize alarm fatigue and improve patient safety. Understanding factors that affect alarm management practice will hopefully guide simulated learning experiences and focused education and training for ICU nurses, to effectively manage monitoring alarms and improve alarm and patient safety.

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doi:10.1097/ncq.0000000000000436APPENDICES

APPENDIX A: DATA ANALYSIS AUDIT TRAIL

I used Braun and Clarke's (2006) thematic analysis to identify themes to analyze and address my research question. During the first stage of becoming familiar with the data (Braun & Clarke, 2006), I found that the overall factors that affected alarm management and alarm response among participants included the noise of the unit, how busy the nurses were, the acuity of the patients, and the number of alarms the ICU nurses would hear during a shift. This also included the presence of an increasing number of false and nonactionable alarms. Other factors included the nurses experience, personality, their knowledge of alarm management, and their situational tiredness or burnout.

In the second step of generating initial codes (Braun & Clarke, 2006), I worked through each of the 12 transcripts to code every segment of text that seemed relevant to address how ICU nurses make decisions regarding alarm management. I identified different codes, for example the noise of the unit and inadequate staffing as factors that reduced the alarm management response among nurses. Other early codes included quicker alarm management response observed in ICU patients that were most acute, and in patients with higher priority alarms. I compared the codes and modified them between different transcripts. I highlighted and corresponded them with appropriate aspects of the data, and then matched the data together as different segments and patterns began to form (Braun & Clarke, 2006). I began to classify potential patterns, such as the busyness and noise of the unit, and perceived severity of patients and alarms, and matched and organized these aspects of data in a separate Microsoft Word document.

I began to search for themes during the third stage (Braun & Clarke, 2006), and I noticed that several codes fit together. For example, I had several codes, including quicker alarm management response, more proficient response and awareness of alarms, and better

troubleshooting of alarms observed in more experienced ICU nurses. I collated these codes into an initial theme of triaging alarms based on nurse experience. At the end of this stage, I collated significant aspects of codes into the following 3 themes: (1) hear it, (2) triage it, and (3) deal with it. In the first “hear it” theme, I highlighted environmental factors and unit noise as sub-themes that were factors that affected how ICU nurses heard various alarms. In the second “triage it” theme, I highlighted different sub-themes, such as nurse years of experience, nurse character, and severity/acuity of patient and alarms, as they all affected how the nurses prioritized their alarm management response. Lastly, in the “deal with it” theme, I focused on different alarms and alarm-related situations that warranted quicker or slower alarm management responses among the nurses.

In the next step, I reviewed the themes and ensured the coded data formed coherent patterns, and assessed whether the themes worked in the context of the entire data I gathered from the interviews (Braun & Clarke, 2006). For example, I eliminated physical environment/equipment and technology as a theme, and incorporated it into the “hear it” theme, as a factor that led to increased false and nonactionable alarm and contributed to overall unit noise. By the end of this phase, I had a good idea of what the different themes regarding alarm management were, how they belong together, and the overarching story they told me about the collected data (Braun & Clarke, 2006). During the fifth stage, I had three clearly defined themes in the final analysis, and organized them into a step diagram. I derived three main themes that capture how ICU nurses respond to alarms, that make up the steps to their decision making: (1) awareness and how the nurses hear the alarms, (2) then how the nurses triage the alarms, and (3) and how the nurses lastly prioritize and respond to the alarms.

APPENDIX B: CHREB APPROVAL



Conjoint Health Research Ethics Board
Research Services Office
2500 University Drive, NW
Calgary AB T2N 1N4
Telephone: (403) 220-2297
chreb@ucalgary.ca

CERTIFICATION OF INSTITUTIONAL ETHICS APPROVAL

The Conjoint Health Research Ethics Board (CHREB), University of Calgary has reviewed and approved the following research protocol:

Ethics ID: REB21-0202
Principal Investigator: Kathryn King-Shier
Co-Investigator(s): Donna Shelley Raffin Bouchal
Student Co-Investigator(s): Nikola Krakova
Study Title: Alarm Fatigue in Intensive Care Unit Nurses
Sponsor:

Effective: 20-Dec-2021

Expires: 20-Dec-2022

The following documents have been approved for use:

- Recruitment Manager Letter to Staff
- Recruitment Poster
- Initial Approval Letter to Manager
- Oral Consent, 1, May 5, 2021
- Beginning Interview Guide
- Demographic Data Form
- Research Proposal, 1, July 13, 2021
- Resilience, Wellness and Mental Health Resource Guide
- Employee and Family Assistance Program (EFAP) Brochure
- Budget Summary

The CHREB is constituted and operates in accordance with the current version of the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans* (TCPS); International Conference on Harmonization E6: Good Clinical Practice Guidelines (ICH-GCP); Part C, Division 5 of the Food and Drug regulations, Part 4 of the Natural Health Product Regulations and the Medical Device Regulations of Health Canada; Alberta's Health Information Act, RSA 2000 cH-5; and US Federal Regulations 45 CFR part 46, 21 CFR part 50 and 56.

You and your co-investigators are not members of the CHREB and did not participate in review or voting on this study.

Restrictions:

This Certification is subject to the following conditions:

1. Approval is granted only for the research and purposes described in the application.
2. Any modification to the approved research must be submitted to the CHREB for approval.
3. An annual application for renewal of ethics certification must be submitted and approved by the above expiry date.
4. A closure request must be sent to the CHREB when the research is complete or terminated.

Approval by the REB does not necessarily constitute authorization to initiate the conduct of this research. The Principal Investigator is responsible for ensuring required approvals from other involved organizations (e.g., Alberta Health Services, community organizations, school boards) are obtained.

Approved By:

Stacey A. Page, PhD, Chair, CHREB

Date:

20-Dec-2021

Note: This correspondence includes an electronic signature (validation and approval via an online system).



Conjoint Health Research Ethics Board
Research Services Office
2500 University Drive, NW
Calgary AB T2N 1N4
Telephone: (403) 220-2297
chreb@ucalgary.ca

CERTIFICATION OF INSTITUTIONAL ETHICS APPROVAL

Ethics approval for the following research has been renewed by the Conjoint Health Research Ethics Board (CHREB) at the University of Calgary. The CHREB is constituted and operates in compliance with the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans* (TCPS 2); Health Canada Food and Drug Regulations Division 5; Part C; ICH Guidance E6: Good Clinical Practice and the provisions and regulations of the Health Information Act, RSA 2000 c H-5.

Ethics ID: REB21-0202_REN1
Principal Investigator: Kathryn King-Shier
Co-Investigator(s): Donna Shelley Raffin Bouchal
Student Co-Investigator(s): Nikola Krakova
Study Title: Alarm Fatigue in Intensive Care Unit Nurses
Sponsor:
Effective: 20-Dec-2022 Expires: 20-Dec-2023

Restrictions:

This Certification is subject to the following conditions:

1. The research as described in the application is approved.
2. Proposed modifications must be approved prior to implementation.
3. An application for renewal must be made annually.
4. Closure requests must be submitted when the research is complete or terminated.

Approved By:

Kathleen Oberle, PhD, Vice-Chair, CHREB

Date:

5-Dec-2022 10:20 AM

Note: This correspondence includes an electronic signature (validation and approval via an online system).

APPENDIX C: AHS APPROVAL



**Health System Access (HSA)
Study Summary &
Administrative Approval For Research to Proceed**
January 18, 2022

Study Information				
Title: Alarm Fatigue in Intensive Care Unit Nurses	Expected End Date:	December 16, 2022		
	Expected No. of Subjects:	24		
	Study Type	Observational		
	Intervention Type (if applicable):	Choose an item.		
Research Ethics Board				
REB #:	REB21-0202	REB Approval Date:	December 20, 2021	
Research Finance				
Funding Source	None	Sponsor/Funder Name(s)	Unfunded	
Financial Account Administered by:	Choose an item.		Account Reference Number(s):	
Purchased Services Agreement Executed				
Lab	DI	Pharmacy	HIM	Other (specify):
Choose an item.	Choose an item.	Choose an item.	Choose an item.	Choose an item.
Principal Investigator:		Primary Contact:		
Name:	Kathryn King-Shier	Name:	Nikola Krakova	
Faculty:	Nursing	Phone:	[REDACTED]	
Department:	Nursing	Email:	[REDACTED]	
University:	University of Calgary			
Phone:	[REDACTED]		Christine Lange	
Email:	[REDACTED]			

A. Study Summary

The anticipated outcome of the research study is to identify patterns across the interview data and relationships between the themes to illustrate the factors that affect nurses' alarm management in critical care. The goal is to identify factors that influence the nurses' decision-making process and customization of clinical alarms, and factors that could contribute to alarm fatigue. As clinical decision making processes are vital for developing appropriate policies, training and education, I hope to contribute to effective interventions at reducing alarm fatigue.

Overall, the potential scientific or scholarly benefit is to contribute to the development of new knowledge, educational strategies, or practice guidelines or tools that support alarm management, to minimize alarm fatigue and improve patient safety.

B. Population under Recruitment:

Nurses who have at least six months of experience, so they may be able to provide detailed information about their alarm management experiences. It is important to recruit nurses who are accustomed to working with various types of technology and alarms in an environment with repeated background noise to discuss their experiences regarding alarm management in detail.

C. Operational Impacts:

The study will utilize access to Alberta Health Services staff that will be interviewed via Zoom (approximately 45 minutes), which will be staff that currently work in adult Calgary Intensive Care Units (ICUs), including South Health Campus ICU, Rockyview General Hospital ICU, Foothills Medical Centre ICU, and Peter Lougheed Centre ICU.

To utilize this access, a letter will be sent out by the unit managers at different ICUs to their nursing staff to recruit potential participants. A letter will be sent to nursing staff by the ICU nursing managers, and posters will be placed in strategic areas on the units.

Operational Areas Impacted / Approvers					
Unit/ Program	Facility	City/Town	Approver Name	Title	Approval Date
Intensive Care Unit	Peter Lougheed Hospital	Calgary	Emma Folz Assessor: Patty Infusino	Executive Director, Administration	January 18, 2022
Intensive Care Unit	Foothills Medical Centre	Calgary	Holly Mackin Assessor: Kelly Coutts	Executive Director Surgery, Trauma Services, Critical Care & SAOTDP	January 12, 2022
Intensive Care Unit	Rockyview Hospital	Calgary	Teresa Thurber Assessors: Melissa Redlich,	Executive Director, Critical Care, ED, NICU, Women's Health, Respiratory	January 12, 2022
Intensive Care Unit	South Health Campus	Calgary	Paul Stewart Assessor Rachel Taylor	Executive Director, Cardiac/Critical Care/Emergency	January 12, 2022

D. Data/System Impacts:

At this time there is no need to access patient health information from AHS sources. If this changes the PI must notify Health System Access to put a Data Disclosure Agreement in place.

Data Disclosure Agreement Status: Not Required.

AHS Administrative Approval (All Zones Except Edmonton):

Date Issued	Name of Approver	Title	Approved
January 18, 2022	Mary-Ann Podgorski	Advisor, Health System Access	



APPENDIX D: TCPS 2: CORE CERTIFICATE OF COMPLETION

PANEL ON
RESEARCH ETHICS

Navigating the ethics of human research

TCPS 2: CORE



Certificate of Completion

This document certifies that

Nikola Krakova

*has completed the Tri-Council Policy Statement:
Ethical Conduct for Research Involving Humans
Course on Research Ethics (TCPS 2: CORE)*

Date of Issue: **20 October, 2019**

APPENDIX E: INITIAL APPROVAL LETTER TO MANAGER

This letter was provided to ICU managers to obtain their permission to recruit potential participants on their units.

Hello,

My name is Nikola Krakova, and I am a practicing Intensive Care Unit (ICU) Registered Nurse, and a Master of Nursing student at the University of Calgary. I am currently working on a thesis focused on ICU nurses' alarm management practices, under the direction of Dr. King-Shier. I would like to speak to your nurses about their decision making regarding alarm management. My objective is to obtain a clearer understanding of how ICU nurses make decisions in alarm management, with goal of contributing to the development of future educational initiatives or policies. Your nurses' participation in the study will be completely voluntary and confidential. I will require you to send out the e-mail with the study information to your nurses on my behalf. Would you be willing to allow me to access your nurses for this study?

I have attached the poster for more information about the study. If you require any further information, please let me know.

Sincerely,

Nikola Krakova, RN MN Student UCalgary

APPENDIX F: MANAGER LETTER TO STAFF AND POSTER

This letter was provided to the ICU managers to distribute to their nursing staff via email.

Hello,

My name is Nikola Krakova, and I am a Master of Nursing student at the University of Calgary. I am working on a study focused on Intensive Care Unit (ICU) nurses' alarm management practices. We would like to speak to ICU nurses about their decision making regarding alarm management.

We invite you to participate in this study if you are a Registered Nurse currently working in an ICU.

If you volunteer to be in this study, your participation will consist of an interview via telephone or Zoom, which will take approximately 45 minutes of your time. Participation in this study is voluntary and confidential.

To learn more about this study, or to participate in this study, please contact Nikola Krakova.

Sincerely,

Nikola Krakova, RN MN Student UCalgary

This poster was placed in the ICUs to help with recruitment of potential participants. It was also included as an electronic attachment in the email the ICU managers distributed to their nursing staff.



**UNIVERSITY OF
CALGARY**

ALARM MANAGEMENT

**We are looking for volunteers to take part
in a study about Intensive Care Unit nurses'
alarm management practices.**

We invite you to participate in this study if you are
an Intensive Care Unit Registered Nurse.

If you volunteer to be in this study, your participation
will consist of an interview via telephone or Zoom,
which will take approximately 45 minutes of your
time.

**To learn more about this study, or to participate in
this study, please contact:**
Nikola Krakova, BScN, MN Student
Faculty of Nursing, University of Calgary
Email: [REDACTED]
Phone: [REDACTED]

**This project has been approved by the Conjoint Health Research
Ethics Board (REB21-0202).**



APPENDIX G: VERBAL CONSENT

This verbal consent script was used during initial data collection.



UNIVERSITY OF CALGARY

ORAL CONSENT TO PARTICIPATE IN RESEARCH

Hello,

My name is Nikola Krakova. I am conducting interviews about Intensive Care Unit (ICU) nurses' alarm management practices. I am conducting this research study as a Master of Nursing student at the University of Calgary. I am working under the direction of Dr. King-Shier of University of Calgary's Faculty of Nursing.

You were identified as a potential participant in this study because you are a Registered Nurse practicing in an ICU in Calgary, with at least six months of critical care experience.

The purpose of this research study is to explore ICU nurses' decision making regarding alarm management. We need a clearer understanding of how ICU nurses make decisions in alarm management before educational initiatives or policy development can occur.

Your participation in the interview is completely voluntary. If you agree to participate, we will ask you to provide responses to several questions regarding alarm management practices. We

will also obtain demographic data, such as the years of your ICU experience, and your full-time, part-time, or casual employment status.

Participation will take a total of about 45 minutes of your time, conducted via telephone or Zoom. I will audio-record the interviews, and then transcribe the questions and your responses verbatim.

We will not identify you or use any information that would make it possible for anyone to identify you in a presentation or written reports about this study. We might want to use direct quotes from you, but your anonymity will be guaranteed by removing personal identifiers from your quotes. We will use a pseudonym when reporting your responses. All members of the research committee that will have access to the data are aware of the responsibilities concerning your privacy and confidentiality. The data will be stored on the secure University of Calgary's OneDrive. The personal laptop used to access the secure University of Calgary storage will be password protected. The data will be retained for five years from the date of project closure, as per the University of Calgary Research policies. The data will be stored in a de-identified state.

You may contact me with any questions or concerns about the research or your participation in this study.

If you have any questions concerning your rights as a participant in this research, please contact the Chair, Conjoint Health Research Ethics Board, University of Calgary.

Do you have any questions or would like any additional details?

Taking part in this study is your choice. You can choose whether or not you want to participate. Whatever decision you make, there will be no penalty to you. You have a right to have all of your questions answered before deciding whether to take part. There are no anticipated risks to you. There are no expected alternatives or benefits to you either. If you decide to take part, you may leave the study until your responses are included in the analysis process.

In no way does your agreement to take part this study waive your legal rights nor release the investigators or involved institutions from their legal and professional responsibilities.

Do you agree to participate in this study?

APPENDIX H: DEMOGRAPHIC INFORMATION FORM

This demographic information form was completed during initial data collection.

- 1) Age of ICU nurse:

- 2) Years of ICU experience:
 - More than 6 months – less than 2 years
 - 2 years – less than 5 years
 - 5 years – less than 10 years
 - 10 years – less than 20 years
 - 20 years or more

- 3) Employee status in ICU:
 - Full-time employment
 - Part-time employment
 - Casual employment

- 4) Shifts worked in ICU:
 - Day shifts
 - Night shifts
 - Both day and night shifts
 - Other, please specify:

5) Role in ICU:

- Bedside RN
- Outreach RN
- Nurse Clinician
- Nurse Educator or Resource Nurse
- Other, please specify:

APPENDIX I: INTERVIEW QUESTIONS

- 1) Tell me about yourself and your work within the ICU.
- 2) How do the clinical alarms affect you? How do they affect your practice?
- 3) Who responds to alarms on your unit? When do they respond?
- 4) What factors affect your response to alarms on your unit?
- 5) How did you receive training on using monitor on your unit?
- 6) How or when do you communicate with your colleagues regarding your alarm settings?
- 7) When do you customize alarms during your shift? How often do you customize them? Do you turn on or off any parameters while customizing the alarms?
- 8) How has the COVID-19 pandemic affected your alarm management practice?
- 9) Does the term alarm fatigue mean anything to you? If so, what is your understanding of it? What does this term mean to you?

APPENDIX J: ADDITIONAL EXEMPLAR QUOTES

Participant	Data Findings Section	Quote
Martha	Step: Awareness Factor: Increased Overall Unit Noise	Sometimes when you are bombarded with noise all the time, you just block it out or get desensitized to it overtime...With all of the noise on the unit, I find that I come home and I am just so overstimulated, and I take all of the different kind of beeps and just the overall noise home with me.
Killian	Step: Awareness Factor: Increased Overall Unit Noise	In terms of overall situational or environmental factors, we are in constant auditory stimulation which is not natural. Alarms are designed to trigger our human alertness and stress responses. Despite the obvious importance and necessity of alarms, working in all this stimulation unfortunately leads to alarm fatigue and burnout.
Trudy	Step: Awareness Factor: Inadequate Staffing	It is not always the nurses' abilities that affects their alarm management, it is sometimes because they are doubled and they are in the other patient's room already dealing with other tasks, so it is inevitable that there are going to be more alarms with less staff on the unit. We sometimes have to double a lot sicker or acute patients, which has also increased the number of alarms going on the unit.
Martha	Step: Awareness Factor: False and Nonactionable Alarms	Sometimes you block it out after a while when you are so tired of hearing the same thing over and over again. Some days I go home, and my ears are still ringing from all the alarms I hear during a shift. Some days I am sitting right beside my patient and the monitor and my patient's alarm is ringing, and someone else will let me know that the alarm is ringing because I did not even notice it.

Walter	Step: Awareness Factor: False and Nonactionable Alarms	The alarms go off so frequently in the ICU, that you definitely become numb to most alarms, unless there are of course serious known issues going on. It feels that every time you hear a triple alarm, you want to silence it right away because you almost always expect that it is not real. My initial reaction is that I just need to silence it first, because it is now easy to assume that nothing is wrong.
Grace	Step: Awareness Factor: False and Nonactionable Alarms	I think alarm fatigue leads to complacency in responding to alarms, and I think it has the ability to be unsafe in that people can get so tired of hearing alarms. They tune them out and then get used to them, and then do not respond when they need to respond to those alarms.
Frances	Step: Awareness Factor: False and Nonactionable Alarms	Sometimes you get to a point in the day where the alarms have been going off constantly and you start to automatically silence everything and it gets dangerous after a while. Nurses need to either do something about the patient or adjust the alarm if it is an acceptable finding. Constantly silencing these is just not a reasonable option.
Dorothy	Step: Triage Factor: RN Years of Experience	I find that if you are training, or you are new to the ICU, and you have not caught onto the alarms yet because you are so focused on what you are learning and your new skills and your own patient, that you have not learned to develop that understanding that there is more going on around the unit than what you have in front of you. Being a more junior staff makes a big difference, as sometimes it can be overwhelming to look at an alarm that keeps ringing and not know what is going on or what to do about it.

Dorothy	Step: Triage Factor: RN Nature/Character	Some people are quicker to respond to alarms than others, which comes down to the personality of the nurse. Some nurses are more assertive and have more of that leadership in them to manage alarms more efficiently.
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