A DNP PROJECT

Improving Clinical Alarm Fatigue and Alarm Management Competency Among Critical Care Nurses by Implementing a Unit Based Alarm Management Bundle

A Project Presented to the Faculty of Keigwin School of Nursing

Jacksonville University

In partial fulfillment of the requirements

For the Degree of Doctor of Nursing Practice

by

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Date: April 13, 2022

Acknowledgements

I want to first thank God for directing my path and guiding me through this journey with endless love and faith. To Him be all the glory for achieving this milestone. To my parents, Alan and Jennifer Bosma, thank you for always supporting my dreams and giving me the confidence and motivation to achieve my goals both professionally and personally. I would not be here today without their unconditional encouragement, dedication, and love. I also want to thank my sisters, Samantha Seedorff and Stacy Bosma, for being my unwavering best friends and biggest cheerleaders in life. To my boyfriend, Derek Makimaa, thank you for getting me to the finish line of this journey and always motivating me to pursue my best. A huge thank you to my amazing nurse leadership team and coworkers for making this project possible and supporting me every step of the way. Lastly, words cannot express how grateful I am for Roberta Christopher and all the hard work she has poured into this project as my DNP chair. She has been a mentor to me since my first class of graduate school and has without a doubt been my fearless leader during this journey. Her dedication to her students is unmatched, and I would not have completed this program without her. A thank you will never be enough to express my gratitude. The utmost respect and appreciation for you all!

ABSTRACT

Clinical alarms are designed to signal an unsatisfactory patient physiological state, alert staff to malfunctioning medical equipment or systems, and warn the operator of potential hazards to the patient. While alarms interrupt the patients healing process, alarms also induce a crippling fatigue among nurses, known as alarm fatigue. The concept of alarm fatigue and clinical alarm management competency remains a common problem among nurses who work in the acute care setting. In the Surgical Intensive Care Unit (SICU) at a teaching hospital in Northeast Florida, alarm fatigue, consistent alarm management skills, and competency surrounding the use of the Philips physiologic monitoring systems were noted to be a problem among nurses working in the SICU. The goal of the DNP quality improvement project was to improve nursing competency associated with alarm management skills and decrease alarm fatigue through the implementation of an evidence-based alarm management bundle, called the CEASE bundle. A pre-and post-intervention HTF clinical alarms survey was distributed to 115 full-time nurses to gather their perceptions of alarm fatigue and management. Overall, nurse participants demonstrated improved alarm management competency, which resulted in significant improvements in their perceptions of alarm functionality, settings, response, and policy adherence. There was a statistically significant decrease in self-reported alarm fatigue post project intervention, and the CEASE bundle was found to be influential to nursing practice.

Keywords: nurse perception of alarm fatigue, clinical alarm fatigue, alarm management competency, alarm management skills, alarm management bundle

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Improving Clinical Alarm Fatigue and Alarm Management Competency Among Critical Care Nurses by Implementing a Unit Based Alarm Management Bundle

Problem Description

In every acute care hospital, noise is inevitable. Alarms in particular play a large role in producing distracting and frequent noises that hinder the nurse's ability to care safely for the patient. While bothersome and cacophonous in nature, clinical alarms are designed to signal an unsatisfactory patient physiological state, alert staff to malfunctioning medical equipment or systems, and warn the operator of potential hazards to the patient. This protective mechanism results in an overabundance of "true" and "false" alarms based on the way manufacturers design alarm systems. With high sensitivity and low specificity, alarm systems are constructed with generalized alarm parameters that are not specific to patient conditions. Due to the high sensitivity and low specificity nature of the monitoring systems, alarms sound roughly 942 times per day in a critical care unit (Bach, Berglund, & Turk, 2018).

While alarms interrupt the patients healing process, alarms also induce a crippling fatigue among nurses, known as alarm fatigue. Alarm fatigue occurs when clinicians are exposed to an overwhelming number of alarms, particularly non-actionable alarms, that causes alarm desensitization among staff (Jepsen, 2018). Nurses become fatigued to these alarms, given that 80%-99% of alarms are found to be false, which delays the response time from the nurse. In order to address the high volume of alarms, nurses are responsible for configuring and customizing clinical alarm parameters in order to protect the patient and reduce the number of nonactionable or false alarms to reduce alarm fatigue and initiate a quick response time from clinical staff (Bach et al., 2018).

The work environment of critical care nurses (CCNs) was studied by Sundberg, Olausson, Fridh, and Lindahl (2017) in an eight-bed general Intensive Care Unit (ICU). The authors discovered that the work environment for CCNs was unhealthy and directly related to nursing burnout due to occupational stressors and advanced technology (Sundberg et al., 2017). Similarly, a quasi-experimental study was conducted in the Pediatric Intensive Care Unit (PICU) at the Mayo Clinic in Rochester, where medical alarms were found to be the loudest and most interruptive noise causing patient and staff discomfort (Kaur, Rohlik, Nemergut & Tripathi, 2016). This is mainly attributed to the complex nature of physiologic monitors and s relation to clinical alarm system safety. Therefore, nurses need to integrate applied knowledge, critical thinking, and psychomotor skills to operate the monitors safely to make clinical decisions. However, there is a current gap in education regarding proper alarm management skills surrounding these intricate monitoring devices. As a result of ineffective alarm management skills and decreased confidence in navigating these physiologic monitoring systems, the number of alarms increases, and alarm fatigue among CCNs worsens (Phillips et al., 2020).

Local Problem Description

In the Surgical Intensive Care Unit (SICU) at a teaching hospital in Northeast Florida, consistent alarm management skills and competency surrounding the use of the Philips physiologic monitoring systems were noted to be a problem among nurses working in the SICU. Therefore, the clinical question emerged: Does alarm management competency increase, and alarm fatigue decrease, when a standardized alarm management bundle is implemented in the SICU at a Northeast Florida teaching hospital? Therefore, the goal of the DNP project was to improve competency associated with alarm management skills and decrease alarm fatigue among

nurses working in the SICU through implementation of an evidence-based alarm management bundle and educational seminar.

Available Knowledge

The effects of inconsistent education regarding the management of alarms and its correlation with alarm fatigue amongst nurses working in the SICU is the clinical practice problem. Based on this problem, how could decreasing alarm fatigue among critical care nurses and implementing a unit-based alarm management bundle increase nurse competency in the management of clinical alarms? To answer this proposed question, nursing databases from the library at Jacksonville University were accessed, specifically, CINAHL, EBSCO, Ovid and ProQuest. The keywords used to narrow the search included *nurse perception of alarm fatigue, clinical alarm fatigue, alarm management competency, alarm management skills,* and *alarm management bundle*. Noted delimiters were peer reviewed, full text and English language articles that were published between 2014 and 2022.

Using the listed keywords and delimiters resulted in the discovery of thousands of articles for review. Sources were then excluded if nurse perception of alarm fatigue, clinical alarm fatigue, alarm management competency, alarm management skills, alarm management attitudes, and alarm management bundle were not among the primary objectives of the article. As a result, 19 articles were selected for review. From the selected sources, five common concepts illuminated the search. The first concept focused on understanding nurses' perception of alarm fatigue and provided the necessary education on the topic. The second concept researched alarm management interventions and implementation strategies. The third concept reviewed alternative methods to combat and measure alarm fatigue. The fourth concept focused on the ICU work environment in relation to nurse turnover and job satisfaction. Finally, the fifth concept studied

the knowledge, skills, and attitudes associated with alarm management and clinical alarm monitoring systems.

First Concept: Measuring Nurse's Perception of Alarm Fatigue

Four references focused on understanding and enlightening nurses on alarm fatigue (Allan, 2018; Cameron & Little, 2018; Casey, Avalos & Dowling, 2018; Petersen & Costanzo, 2017). All four sources were quality improvement initiatives that measured nurse's perception of alarm fatigue and educated staff on alarm management compliance strategies. The Healthcare Technology Foundation (HTF) survey was used to gain a better understanding of how nurses perceived alarm fatigue before and after implementing educational interventions. From the results of the pre-intervention HTF survey, Casey et al. (2018) concluded that nurses perceived alarm fatigue from intense alarm load and reoccurring non-actionable alarms. Therefore, the interventions targeted decreasing alarm load and alarm management strategies (Allan, 2018; Cameron & Little, 2018; Casey, Avalos & Dowling, 2018; Petersen & Costanzo, 2017).

The interventions implemented in the four quality improvement initiatives were: forming an alarm management protocol, creating easy usage tools for monitoring systems, providing educational sessions utilizing hands on training, and conducting alarm management skills assessments. As a result of the post project HTF survey results from Casey et al. (2018), alarm fatigue among ICU nurses decreased and knowledge regarding alarm fatigue and alarm management strategies increased. Recommendations for future study regarding alarm fatigue and evidence-based alarm management strategies included continued education and implementation of standardized, unit based, alarm management policies (Allan, 2018; Cameron & Little, 2018; Casey, Avalos & Dowling, 2018; Petersen & Costanzo, 2017).

Second Concept: Alarm Management Bundle Implementation

Five sources focused on understanding alarm systems and implementing alarm management bundles into clinical practice (Bach et al., 2018; Jepsen, 2018; Lewis & Oster, 2019; The Joint Commission, 2022; Turmell et al., 2017). Primarily, Bach et al. (2018) conducted a literature review to better understand alarm standards as well as how to effectively manage and improve the quality and safety of alarm systems in healthcare. From the review, 21 articles and seven publications on quality improvement alarm work were included in the analysis.

Among the literature, 10 themes of improvement emerged and were categorized into technical, human, and organizational factors. Technological factors included machine learning, alarm configuration, and alarm design. Human factors included alarm training and education, multidisciplinary teamwork, and alarm safety culture. Organizational factors included alarm protocols and standard procedures, alarm inventory and prioritization, alarm assessment and evaluation, and education. Machine learning was found to improve alarm safety by developing smart alarms to analyze clinical data for multiple patients and trend various alarms to decide whether an alarm was determined to be actionable or nonactionable. Alarm configuration and alarm design was defined by reconfiguring alarm parameters to actionable levels in order to reduce the number of false alarms. However, individualizing alarm parameters per patient tends to lack standardization amongst organizations and therefore would require education from experienced nursing staff and leadership to redesign alarm settings (Bach et al., 2018).

Continuing, suggested human factors included alarm training and education, multidisciplinary teamwork, and alarm safety culture. Ten of the twenty-one studies highlighted the need for standardized alarm protocols. The literature uncovered a lack of training surrounding alarm systems, management, and safety. The study suggested integrating systematic

and interactive educational seminars and training during meetings and clinical rounds to address staff needs and patient safety concerns. Forming a multidisciplinary team to educate staff on effective alarm management strategies was found to be imperative in improving the functionality, safety, and consistency of alarm systems. The literature suggested establishing patient specific alarms, documenting alarm parameters in the patient's chart to improve alarm configuration compliance, agreeing on when it is safe to pause or silence an alarm, adjusting staffing models to respond to alarms quickly, and reinforcing daily ECG electrode replacement. Ultimately, assessing, evaluating, and prioritizing alarm management interventions required staff compliance and commitment to follow best practice guidelines (Bach et al., 2018).

Jepsen (2018) completed a literature review to recommend interventions that could reduce alarm fatigue and enhance effective alarm management in practice. The studied interventions were broken up into categories for bedside care providers and nursing leaders. The four interventions for bedside care providers included adequate skin prep prior to changing electrocardiogram (ECG) electrodes daily, using appropriate oxygen saturation probes, checking alarm settings, and customizing alarm parameters for each patient. For nurse leaders, the four interventions included organizing an interprofessional team to manage alarms, developing unit specific alarm default parameters, providing continuous education on alarm management, and only monitoring clinically appropriate patients (Jepsen, 2018). The Joint Commission (2022) had the same recommendations for nurse leaders to manage alarms safely and effectively in the clinical setting and agreed that alarm safety was a multifaceted problem.

Similarly, Lewis and Oster (2019) introduced an evidenced based, nurse driven, patient specific customization alarm management bundle focused on communication, electrodes, appropriateness, setup, and education (CEASE). The proposed research question sought to study

the application of the CEASE bundle and evaluate its influence on alarm load, alarm fatigue and nurse perception of alarm fatigue. ‘Communication’ focused on working with colleagues (fellow nurses, respiratory therapists, providers, and patient care technicians) to identify patient specific goals, as well as determine when to suspend or silence alarms while performing care activities that induce nonactionable alarms. ‘Electrodes’ targeted proper skin preparation for daily ECG electrode and pulse oximeter changes. ‘Appropriate’ encompasses determining what is clinically indicated for the patient and choosing appropriate monitoring parameters with physician and interprofessional team members. ‘Setup’ includes customizing alarm parameters per individual patient at the beginning of each shift. ‘Education’ relates to the need for continued education on the clinical alarm monitoring systems. The study was conducted over a 6-month period and the HTF survey was utilized to evaluate pre- and post-project effectiveness. After implementing the CEASE bundle, Lewis and Oster (2019) discovered that the total number of alarms decreased by 31% and alarm fatigue among nurses improved. The outcomes of the bundle produced a quieter work environment and led to greater patient and nurse satisfaction.

In conjunction, Turmell et al. (2017) constructed an evidence-based alarm management program to improve patient safety and reduce alarm fatigue among nurses. The study incorporated recommendations from the American Association of Critical Care Nurses (AACN) which included daily electrode replacement and proper skin preparation, eliminating nonactionable and duplicate alarms by adjusting default threshold parameters, educating staff on alarm customization, and implementing the proposed guidelines unit wide. Results of the study showed a 30% reduction in alarms and an overall improvement of nurse perception of alarm fatigue (Turmell et al., 2017). This study was closely comparable to Lewis and Oster’s (2019) project with similar interventions and recommendations for future practice.

Third Concept: Alternative Methods to Managing Alarms and Fighting Alarm Fatigue

The following four sources researched alternative interventions to combat and measure alarm fatigue (Kaur et al., 2016; Kobaysahi, Gosbee & Merck, 2016; MacMurchy, Stemler, Zander & Bonafide, 2017; McFarlane et al., 2018). A quasi-experimental study was completed by Kaur et al. (2016) at Mayo Clinic Rochester's PICU to measure healthcare providers and patient perception of noise and implement interventions to reduce the noise level in the PICU. The authors exclaimed how an environment with excessive noise hinders healing, recovery, and job satisfaction. Medical alarms were found to be the number one contributor to excessive noise. Based on the findings, recommendations suggested implementing mobile alarm monitoring systems and educating staff on alarm management techniques to reduce the number of alarms and improve overall nursing job satisfaction (Kaur et al., 2016).

Next, a mixed-method research study was conducted by Kobayashi et al. (2016) to compare a standard telemetry monitoring system with a multiparameter alerting system to eliminate alarm fatigue. The simulation evaluated provider responsiveness to patient alarms and quantified the effects of false alarms on provider recognition. The findings were congruent to Kaur et al. (2016) and suggested further research on monitoring devices and methods to reduce alarm fatigue (Kobayashi et al., 2016). In relation, MacMurchy et al. (2017) studied the acceptability, feasibility, and cost of video monitoring in measuring alarm fatigue and nurse response time. The study analyzed 11,745 alarms and staff responses. The video data captured a large volume of unactionable alarms which resulted in decreased nurse response time. The findings and recommendations were similar to Kobayashi et al. (2016) and suggested further video monitoring research to better understand and manage alarm fatigue (MacMurchy et al., 2017).

A randomized clinical experiment performed by McFarlane et al. (2018) was conducted in a 20-bed simulated acute care hospital to evaluate the effectiveness of a metacognitive attention aid, worn as a watch, that allows clinicians to easily access and manage alarms in the clinical setting. The goal of the study was to assist nurses in triaging various alarms, improve nurse response time, and reduce adverse events and associated healthcare costs. As a result of implementing the wearable attention aid into practice, nurses responded to the bedside 148% faster to clinically actionable alarms. This data supports the hypothesis that giving clinicians the capability to easily access clinical alarms will allow for earlier nursing intervention by recognizing patient trends at a faster rate. The device was found to not only improve nursing response time, but also reduce the workload associated with checking alarms and decrease the number of nonactionable alarms (McFarlane et al., 2018).

Fourth Concept: ICU Work Environment in Relation to Nurse Turnover and Job Satisfaction

Four sources examined the ICU work environment and its correlation between nurse turnover, burnout, intent to leave the job, and job satisfaction (Bys, 2016; Moss et al., 2016; Shanmugham et al., 2018; Sundberg et al., 2017). According to Bys (2016) the cost of turning over an ICU nurse is estimated to cost a facility between $62,000 and $67,000. In order to decrease nurse turnover and intent to leave the job while increasing ICU nurse retention and job satisfaction, Bys (2016) discovered that multiple factors need to be considered such as emotional demands, physical demands, social support, autonomy, and professional development opportunities. Results found that when nurses feel committed to their organization, turnover decreases. Thus, nurses need to be supported from a leadership and environmental standpoint. To better understand the workload of an ICU nurse, Shanmugham et al. (2018) assessed the mental

workload of nurses while operating clinical devices and monitoring patients in order to keep nurses at the bedside. Results from the quantification and comparison study concluded that removing nonessential alarms can improve provider experience, decrease mental workload, and increase overall job satisfaction in the critical care setting (Shanmugham et al., 2018).

Furthermore, a study conducted by Sundberg et al. (2017) discovered that critical care nurses were increasingly vulnerable to developing burnout from occupational stressors. Stressors included high patient acuity, increased responsibility, working with advanced medical technology and caring for families in crisis. Moss et al. (2016) stated that burnout was far too common in healthcare professionals who care for critically ill patients. The development of alarm fatigue induces psychological stress among ICU nurses and negatively impacts the work environment leading to an increased nurse turnover rate (Moss et al., 2016). Stress and a negative work environment had a strong correlation with nurses' intent to leave the bedside. Studies have shown that an improved work environment reduced burnout among nursing staff, minimized the risk for nurse turnover, and increased job satisfaction. Sundberg et al. (2017) discovered that reducing the overall noise level and number of alarms in the ICU had a positive impact on the sound environment and improved nurse's mental health, well-being, and resilience on the job site. Therefore, reducing alarm fatigue among ICU nurses could in turn improve nurse turnover and improve job satisfaction.

Fifth Concept: Alarm Management Knowledge, Skills, and Attitudes

Two sources studied nurses' knowledge, skills, and attitudes towards alarm management and evaluated educational methods to improve alarm management competency. Phillips et al., (2020) recognized the need for integrating knowledge, skills, and critical thinking into safely operating monitors in order to support clinical decisions. As a result, Phillips et al. (2020)

developed an educational toolkit for nurses to utilize as a standardized framework for physiologic monitor use and alarm safety guide. The toolkit assessed the knowledge, skills, and attitudes regarding clinical monitor use and alarm management and was broken down into four competency evaluations. The four competency areas included hardware and connectivity, admission, discharge, and transfer, managing monitor alarms, and appropriate monitoring. The authors recommended that institutions collaborate with their monitor's vendor to align the competency assessment with that of the specific monitoring system for the nurses to obtain an accurate competency skills assessment check-off (Phillips et al. 2020).

Additionally, Sowan et al. (2017) created a nurse competence and Philips physiologic monitor use survey. The survey was validated by 13 ICU nurses, who are experts in their field, and assessed the perceived level of competence in using the Philips monitors. The survey was organized into five subscales with a total of 59 items and two open ended questions. The first item assessed the admission, discharge, and transfer process, the second focused on hardware and connectivity, the third evaluated alarm management, the fourth assessed for appropriateness of monitoring, and the fifth studied advanced functions of the monitor. The nurses were then able to give each statement a confident, neutral, not confident, or never used rating. The percentages were gathered based on responses and results were obtained to identify common knowledge gaps related to monitor competency. This survey identified where there was a common gap in alarm management and competency knowledge, skills, and attitudes. Future recommendations included ongoing education and training surrounding the monitoring systems to streamline and maintain competency.

Synthesis of Evidence: Overall Strength and Quality of Evidence

From the appraisal of the 19 sources, zero were level I, six were level II, 11 were level III, zero were level IV, and two were level V. Both level V sources received a high-quality rating and gave similar recommendations. Creating an alarm management protocol, understanding how nurses perceive alarm fatigue, and reducing the number of alarms to lower noise levels were the most common recommendations (Jepsen, 2018; The Joint Commission, 2019). Next, the majority of the appraised sources were level III (Allan, 2018; Bach et al., 2017; Cameron & Little, 2018; Casey et al., 2018; Kobayashi et al., 2016; MacMurchy et al., 2017; Moss et al., 2016; Petersen & Costanzo, 2017; Phillips et al., 2020; Sowan et al., 2017; Sundberg et al., 2017). All 11 of the level III sources received high-quality ratings. Each source discovered that forming an interdisciplinary team was crucial to educate staff on clinical alarm management strategies by creating and implementing an alarm management bundle and educational competency toolkit in order to reduce alarm fatigue among CCNs, improve alarm management strategies and utilization, and decrease the number of nonactionable alarms.

From the search, six level II sources were identified (Bys, 2016; Kaur et al., 2016; Lewis & Oster, 2019; McFarlane et al., 2018; Turmell et al., 2017; Shanmugham et al., 2018). All the sources were quasi-experimental studies and had the strongest evidence to support their research, thus receiving high-quality ratings. The recommended findings focused on improving alarm management to reduce the number of clinical alarms and reduce the occurrence of alarm fatigue amongst ICU nurses. Strategies also focused on improving the ICU work environment in order to reduce nurse turnover and burnout while improving nurse retention and overall job satisfaction.

Lastly, there were zero level I studies selected for review. This is due to the lack of level I studies that have been conducted on the subject of alarm fatigue and implementing alarm

management policies. However, it would be unethical to conduct a randomized control trial (RCT) and have a control group of staff members be fatigued. Therefore, the common consensus amongst all the sources was that higher level research needs to be conducted to develop standardized alarm management policies to improve alarm fatigue amongst ICU nurses.

Recommendations

Based on the reviewed literature, constructing an evidence based, alarm management bundle was the number one recommendation to reduce alarm fatigue among nurses and improve alarm management skills from experienced to beginner nurses (Bach et al., 2018; Jepsen, 2018; Lewis & Oster, 2019; The Joint Commission, 2022; Turmell et al., 2017). The evidence uncovered the lack of standardized, unit-based alarm management bundles for staff to refer to and follow. Due to the lack of standardization and education, alarm fatigue and the management of clinical alarms is undervalued. Therefore, implementing an alarm management bundle, creating easy usage tools for monitoring systems, providing educational sessions utilizing hands on training, and conducting alarm management assessments were recommended (Allan, 2018; Cameron & Little, 2018; Casey et al., 2018; Petersen & Costanzo, 2017; Phillips et al., 2020; Sowan et al., 2017).

Furthermore, due to the lack of training regarding alarm systems, unit wide education needs to be conducted continuously for seasoned ICU nurses, new graduate nurses, and travel nurses. To begin, forming a multidisciplinary team of staff members to encourage and support this process change of alarm management standardization is crucial. Next, integrating systematic and interactive educational seminars and training during meetings and clinical rounds to address staff needs and patient safety concerns will assist in streamlining education. The literature also recommends customizing patient specific alarms and reviewing alarm parameters at the change

of shift with the oncoming nurse to improve alarm configuration compliance and promote patient safety while reducing nuisance alarms. Simultaneously, agreeing on when it is safe to pause or silence an alarm, such as during a direct patient encounter that may trigger an alarm or providing direct patient care is also highly recommended to avoid false alarms that contribute to alarm fatigue. Finally, reinforcing daily ECG electrode and pulse oximeter changes will decrease the amount of patient artifact and allow for an accurate reading on the monitor. Therefore, implementing an alarm management bundle is warranted to improve alarm management knowledge, skills and attitudes towards clinical alarm monitoring systems and improve alarm fatigue amongst ICU nurses (AACN, 2018; Bach et al., 2018).

Fit, Feasibility, and Appropriateness of Recommendations

The recommendations were compatible with the 2018 American Association of Critical Care Nurses (AACN) practice alert on alarm management. The AACN recommendations for bedside caregivers are as follows: provide proper skin preparation and placement of ECG electrodes, change ECG electrodes daily, properly place and change oxygen saturation probes, verify alarm settings at the start of every shift with the ongoing caregiver or with any change in patient condition, and customize alarm parameter settings to align with the patient's needs and unit or hospital policy. For nursing leaders, strategies to improve alarm management include establishing an interprofessional team to gather data and address alarm related issues, developing unit-specific alarm management strategies and default parameters, provide initial and ongoing education to staff regarding monitoring systems and alarm management techniques, and determining which patients require clinical indication for monitoring (AACN, 2018).

The AACN (2018) recommendations were appropriate and feasible for implementation given the northeast Florida teaching hospital's cultural values and norms of continued education,

research and change. Given the current organizational infrastructure, this practice change was implemented with acceptance. To advance the project, a multidisciplinary team of staff members was formed to spark change and hold one another accountable for maintaining the unit wide alarm management bundle and incorporating the bundle into practice. This change improved ICU nurses' ability to effectively manage alarms for each individual patient while reducing clinical alarm fatigue. Due to the consistency of the findings in the literature, the quality improvement project was accepted and beneficial to the unit.

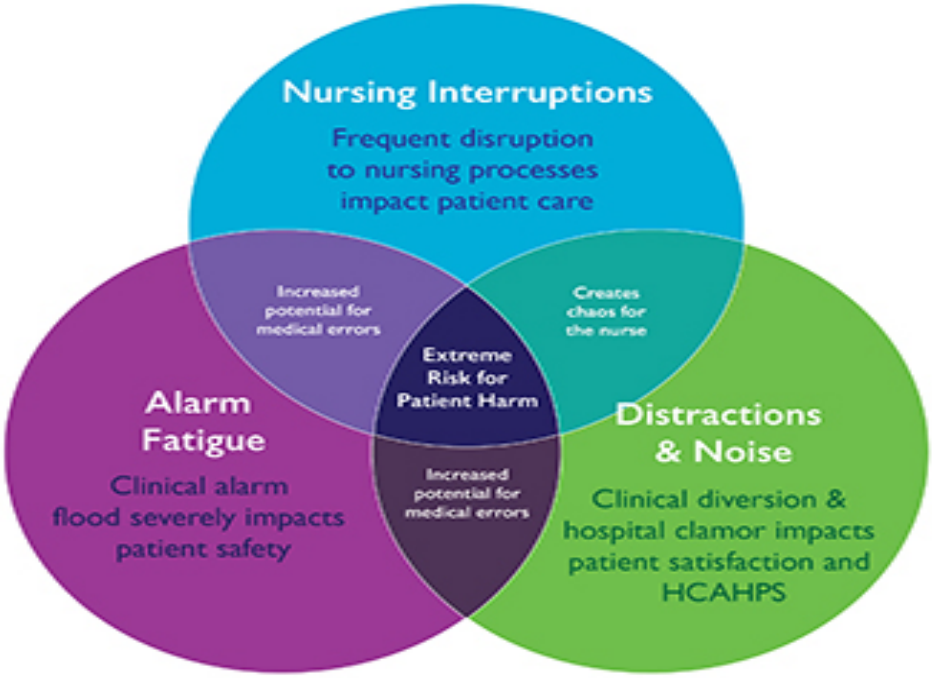
Rationale

Conceptual/Theoretical Framework: Chaos Theory

The conceptual framework that provided theoretically relevant context to the project and problem was the chaos theory created by Lorenz (1963) and later updated by Lopes (2014). The chaos theory explained how complex systems, yet seemingly chaotic, are organized at their core. Similar to the chaos theory, alarms are also complex systems that produce an array of sounds. Therefore, interventions focused on finding the organization behind the chaotic nature of alarms and the associated monitoring systems. Organization was found by creating a unit-based alarm management bundle to streamline alarm monitoring and implementing a standardized process to organize the way nurses manage alarms. By doing so, the chaos behind alarms diminishes, and nurses can distinguish true alarms from false alarms, troubleshoot equipment, and appropriately respond to the patient. The chaos theory rationale is included in Figure 1 as conceptualized by Jahrsdoerfer and McAlpine (2015).

Figure 1

Interruption Fatigue Includes Alarms, Distractions, and Nursing Interruptions



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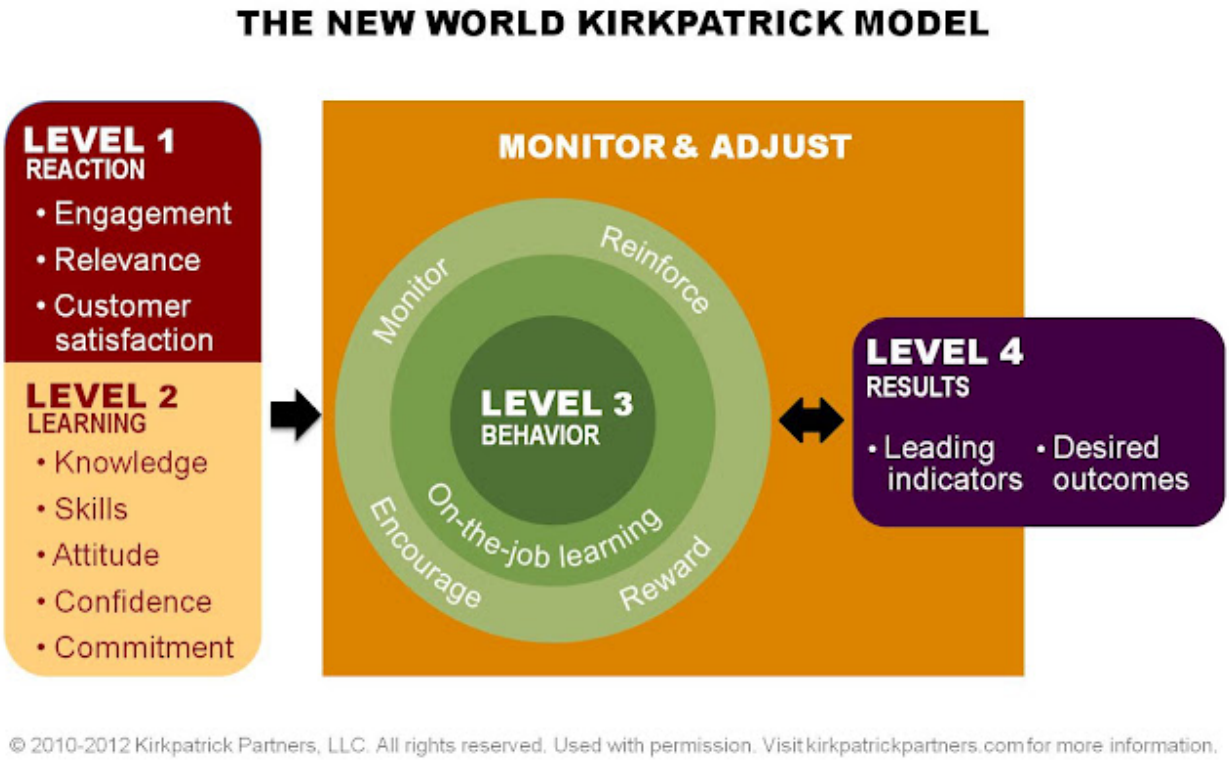
Evaluation of Learning Conceptual Framework: Kirkpatrick Model

In order to evaluate the training after project implementation, the Kirkpatrick model created by Jim and Wendy Kirkpatrick (2019) was utilized. The model is broken down into four levels with the first being reaction, then learning, behavior and results. The first level, reaction, measured the degree to which participants found the training beneficial, engaging, and appropriate for their jobs. The second level, learning, assessed the degree to which participants gathered the knowledge, skills, attitudes, confidence, and commitment associated with their participation in the training. The third level, behavior, evaluated the extent to which participants applied what they learned during training to their job. The fourth level, results, measured

whether targeted outcomes were achieved as a result of the training. By implementing all four levels, the training surrounding the Philips monitoring devices and alarm management strategies were adequately evaluated and changes were made accordingly (Kirkpatrick et al., 2019).

Figure 2

Reaction, Learning, Behavior and Results



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Quality Improvement Model

The chosen evidence-based practice quality improvement model to guide the Doctor of Nursing Practice (DNP) project was the plan-do-study-act (PDSA) model. Since the DNP project sparked change, the PDSA model seamlessly led and encouraged the improvement process. For the PDSA model to be successful in the quality improvement project, goals were set, outcomes were measured, and areas for improvement and change were selected (Pelletier & Beaudin, 2018). The objective of the project was to decrease alarm fatigue and increase alarm

management competency through implementation of an evidence-based alarm management bundle in the SICU. The PDSA quality improvement model served as a guide for project planning, implementation, and measurement of outcomes.

The PDSA model was an ongoing process improvement cycle that allowed for planning a change, implementing the plan, articulating the results, and using those results to guide further improvement (Pelletier & Beaudin, 2018). Therefore, the "plan" was to implement an evidence-based alarm management bundle in the SICU. Based on the review of the literature and recommendations, implementing a standardized alarm management bundle improved the nurse's ability to effectively manage the clinical alarm monitoring systems and in turn decreased the occurrence of alarm fatigue among ICU nurses. The "Do" process occurred over the course of two months. During the first month, the HTF clinical alarms survey was distributed to all nurses during huddles and change of shift. A PowerPoint presentation was presented during the quarterly staff meeting to educate the ICU nurses on the DNP project and alarm management bundle. Following the presentation, the CEASE alarm management bundle was displayed around the unit as a quick referral during the intervention phase and served as a reminder to perform alarm safety checks during bedside shift report when discussing the patient's hemodynamics. The second month consisted of educational seminars, frequent rounds, audits, and project reinforcement along with question and answer (Q&A) sessions to address staff members' thoughts, suggestions, or concerns regarding the alarm management bundle.

The "Study" component was addressed during the third month and assessed the effectiveness of the results post-project implementation. Lastly, the "Act" phase confirmed whether the alarm management bundle was successful in reducing alarm fatigue and improving alarm management skills among nurses and increasing job satisfaction. Based on the success of

the bundle, the PDSA cycle continued until the project goal was reached, or implementation of the alarm management bundle was recommended for other units capable of telemetry.

Specific Aims

The purpose of the DNP project was to decrease alarm fatigue and improve alarm management skills and Philips's monitor competency among CCNs by conducting educational seminars, utilizing hands on training, and implementing an evidence-based alarm management bundle in the SICU. The alarm management bundle standardized the management of clinical alarms and nurses gained confidence in alarm management skills by completing the Philips monitor competency check offs. Therefore, by implementing an evidence-based practice alarm management bundle, alarm fatigue in CCN's decreased and alarm management confidence and competency increased.

1) **Specific Aim 1***: (Inferential Analysis)*
    a) **Outcome Goal A:** There is a statistically significant decrease in self-reported alarm fatigue as measured by the HTF clinical alarms survey pre- and post- project intervention.
    b) **Outcome Goal B:** There is a 30% decrease in self-reported alarm fatigue as measured by the HTF clinical alarms survey pre- and post- project intervention.
2) **Specific Aim 2:** *(Descriptive Analysis)*
    a) **Process Goal A:** A minimum of 70% the SICU nurses will complete the HTF clinical alarms survey.
    b) **Process Goal B:** A minimum of 70% of the SICU's nursing staff will complete the alarm management bundle training, 1:1 discussion by the DNP Project Lead or the Philips monitor representative.

c) **Process Goal C:** A minimum of 70% of the SICU's nursing staff will successfully attend the alarm monitor in service training via the Philips monitor representative and complete the Philips monitor competency check off tool.

3) **Specific Aim 3:**

a) **Process Goal A:** Out of the nurses partaking in the project education, at least 80% are satisfied with the presented education and learning objectives are met.

b) **Process Goal B:** While performing active auditing rounds, at least 60% of the nurses adhere to the alarm check process and implement the CEASE bundle into practice.

4) **Specific Aim 4:**

a) **Outcome Goal A:** Alarm management competency increases following educational seminars and implementation of a unit wide, evidence-based alarm management bundle as measured by HTF clinical alarms survey pre- and post- project intervention and Philips monitor competency check off tool.

b) **Outcome Goal B:** Confidence in alarm management competency increases by 60% following educational seminars and implementation of a unit wide, evidence-based alarm management bundle.

5) Specific Aim 5:

a) **Qualitative Process Goal A:** There is an overall improvement from baseline, in alarm management practices and processes as directly observed and self-reported during weekly shift huddles, staff meetings, and/or rounding via the qualitative interviews or small group discussion in accordance with the alarm management bundle.

b) **Qualitative Process Goal B:** The alarm management practices and processes are successfully implemented and hardwired as qualitatively measured via direct observation

(> 60% of the time observed) and self-reported during weekly shift huddles, staff meetings, and/or rounding via qualitative interviews or small group discussions in accordance with the alarm management bundle.

Context

Specifics of Healthcare Setting and Population

The project took place in a 27 bed Surgical Intensive Care Unit (SICU) at a magnet-level teaching hospital located in Northeast Florida. There were 115 staff nurses working full time, modified full time, or part time. The project excluded as needed (PRN) nurses and travel nurses. There were about 20 patient care technicians, one nurse educator, one clinical nurse specialist, one ECMO coordinator, and one nurse manager. Additionally, there were many respiratory therapists, advanced practice providers (nurse practitioners and physician assistants), residents, fellows, and attending physicians who served and cared for the patients in the SICU. The patient population consisted of those requiring cardiothoracic surgery, heart and lung transplants, neurosurgery, vascular surgery, neurology critical care, and critical care services. Care was also provided to patients needing mechanical devices such as intra-aortic balloon pumps, ventricular assist devices, impellas, continuous renal replacement therapy (CRRT) and life supporting measures such as extracorporeal membrane oxygenation (ECMO).

For the purpose of the DNP QI project, it was important to understand the acuity of the patients receiving care in the unit, however, the project only involved the nursing staff working at a full time, modified full time or part-time schedule who cared for these individuals. Participating in the DNP project was not mandatory, but highly encouraged since it was a unit wide QI initiative. Participation of individual nurses was kept anonymous, although basic demographics were gathered in the survey. Therefore, informed consent was not needed.

Analysis of Strengths and Opportunities for Success in the Healthcare Setting

The incorporation of the project into the healthcare setting was highly favorable. The nursing staff was motivated to learn methods to better manage alarms and navigate the monitoring systems effectively to promote patient safety and decrease alarm fatigue. The support and dedication of the unit nurse manager and nurse educator to improve alarm management competency and alarm fatigue were apparent given the core values of the hospital of patient care, education, and research. Furthermore, there was an ongoing need for education on the management of alarms since there were many new employees that never received formal Philips monitor alarm training. New nursing staff members were exposed and educated on the monitors during a 6–24-week bedside orientation. Therefore, the sole responsibility resided with the preceptor to properly educate the novice nurse on the various alarm settings, configurations, profiles, and alarms embodied in the Phillips monitors. Since there was a lack of systematic training, meetings were held to address questions, concerns, and recommendations for the future to streamline alarm management education.

Impact of Electronic Health Record (EHR), Workflow, and Policies/Procedures

The hospital used the Epic charting system to document information into the EHR. For the purposes of this project, the EHR was not utilized since there was no patient involvement. However, workflow played a large role into the success of the project since the "alarm check" process took place during handoff or when assuming care for a new patient. The alarm check occurred during the review of the patient's hemodynamic status, and it was the nurse's responsibility to verify alarm settings and parameters for each patient. Furthermore, since there was no policy or procedure in place for the management of alarms, there was a known gap in the workflow. Considering this, the CEASE alarm management bundle was incorporated into

practice and aided in educating staff on proper patient parameters, various alarm settings, and strategies for reducing the number of alarms that sound during a given shift.

Support for the Project

The CEASE bundle was presented, printed, and displayed around the unit for easy reference, and the CEASE bundle audit tool was used by the DNP student to audit nurses during rounding. Permission to use both tools was granted by Wolters Kluwer publishing for a one-time fee of $75 (See Appendix A). Before and after the project was implemented, the 2016 HTF Clinical Alarms Survey was distributed to each nurse in the SICU and was completed pre- and post-project initiation. A signed document of intention, along with a $10-dollar donation was submitted to the HTF secretary, and permission was granted to use the HTF clinical alarms survey for the purpose of the DNP project. The survey was used to gain insight into clinical alarms, how often they occurred and the level of fatigue they produced among staff.

During the four-month time frame of project education and implementation, the DNP student coordinated with the nurse educator and invited the Philips monitor representative to visit the unit and provide in-service training sessions on the Philips monitor and answer any questions or concerns the nurses may have surrounding the device. Following the in-service training, a Philips monitor confidence and competency survey was distributed to the nurses and assessed improvement in confidence level and alarm management practices. This came at no cost to the DNP student since it benefited the unit and enhanced patient safety. Finally, there was no cost to print the materials, and a grant was not applied for because this was a low-cost project. The total amount spent on the project by the DNP student was about $100.

Intervention

Jacksonville University IRB and facility approval were obtained, and the DNP project was implemented over the course of four months. The first two to four weeks were spent distributing the HTF clinical alarms survey to all SICU nurses before any education or training was done to assess the current level of alarm fatigue and alarm management competency among CCNs. The HTF clinical alarms survey was created by the Healthcare Technology Foundation in 2016 to improve and research alarm-related issues in healthcare. The original 2011 HTF survey was reviewed and revised by seven HTF board members, all experts in alarm management. The HTF survey received face and content validity during this process and problematic questions from the 2011 survey were excluded in the 2016 survey. The HTF survey measured attitudes and practices towards clinical alarms pre-intervention. The survey was not mandatory but highly encouraged with the goal compliance rate at 70%. Formal consent was not needed to participate in the study since the survey was anonymous.

After the HTF survey results were gathered, education and training on the CEASE bundle and Philips's monitoring system occurred over the next eight weeks. The project intervention phase was broken down into two parts to include education and skills. The educational intervention phase was conducted during two quarterly staff meetings via Zoom. The DNP student presented a short PowerPoint presentation about the CEASE bundle and the CEASE bundle was displayed around the unit for easy reference.

Permission was granted from Wolters Kluwer Health Copyright Clearance Center (See Appendix A) to use the CEASE evidence-based alarm management bundle created by Lewis & Oster (2019) in a research study titled "Research Outcomes of Implementing CEASE: An Innovative, Nurse-Driven, Evidence-Based, Patient-Customized Monitoring Bundle to Decrease

Alarm Fatigue in the Intensive Care Unit/Step-Down Unit". As previously stated, the bundle was implemented into practice in the 27 bed SICU at a northeast Florida teaching hospital. Based on the success of the bundle in the conducted research study, The CEASE bundle served as a sufficient alarm management tool and improved the management of clinical alarms and alarm fatigue among CCNs. The CEASE bundle was broken down into five components (See Appendix B for CEASE bundle tool).

a) Communication: Communicate with coworkers and monitor technicians and pause or suspend alarms when performing care activities that create nonactionable alarms.
    (i) The communication portion was displayed during change of shift when the oncoming and off going nurse performed an "alarm check" to verify patient parameters and alarm settings.
    (ii) The nurses coordinated with the monitor technician in the monitor bank to address any concerns for each patient and instructed the technician when to alert the nurse.
    (iii) The nurses communicated with respiratory therapists to adjust ventilator alarm settings for each patient as needed.
    (iv) Throughout each shift, alarms were suspended or silenced when actively providing patient care that stimulated an alarm such as drawing blood from a patient's arterial line or suctioning a patient on the ventilator.
b) Electrodes: Change ECG electrodes daily or as needed and provide proper skin care prior to placing them correctly on the patient. Change pulse oximeter sensors and check skin integrity daily or as needed.

(i) The ECG electrodes were changed when bathing a patient, as needed if the electrodes were not sticking properly, or if there was a poor reading on the monitor.

(ii) If the patient's extremities were too cool to pick up an oxygen saturation waveform on the monitor, the nurse would contact the respiratory therapist for an ear probe pulse oximeter or other pulse oximetry device.

c) Appropriate: Collaborate with providers and interprofessional team members to assess the appropriateness of ECG, SpO2, CVP, PAP, EtCO2, etc. monitoring for the patient, choose appropriate monitoring parameters, and discontinue monitoring devices when no longer necessary.

(i) The nurses were responsible for assessing the need for monitoring devices and consulted a provider to discontinue orders when therapy was finished.

d) Setup: Customize alarm settings for individual patients by adjusting heart rate, blood pressure, respiratory rate, SpO2 and arrythmia parameters. Do not change alarms for ventricular tachycardia, ventricular fibrillation, or asystole, however, if a patient has known atrial fibrillation (afib), the nurse can use his or her discretion to pause the arrythmia alarm for afib. Customized alarm parameters should be set within one hour of assuming patient care and as patient condition changes to plus or minus 10% of patient baseline.

(i) Alarm parameters were reviewed and confirmed via the "alarm check" by the day and night shift nurse during change of shift. This was done when discussing hemodynamics in the cardiovascular section of the report sheet to help streamline handoff.

(ii) Alarm parameters were adjusted by the nurse throughout the shift to account for changes in patient condition.

e) Education: Educate staff on the monitoring system and various alarm settings.

(i) Education was performed by the DNP student and the Philips monitor representative to cover clinical alarm management strategies, tips and tricks on how to effectively use the monitor and how to change patient profiles to reflect current patient status (i.e., hospice patient).

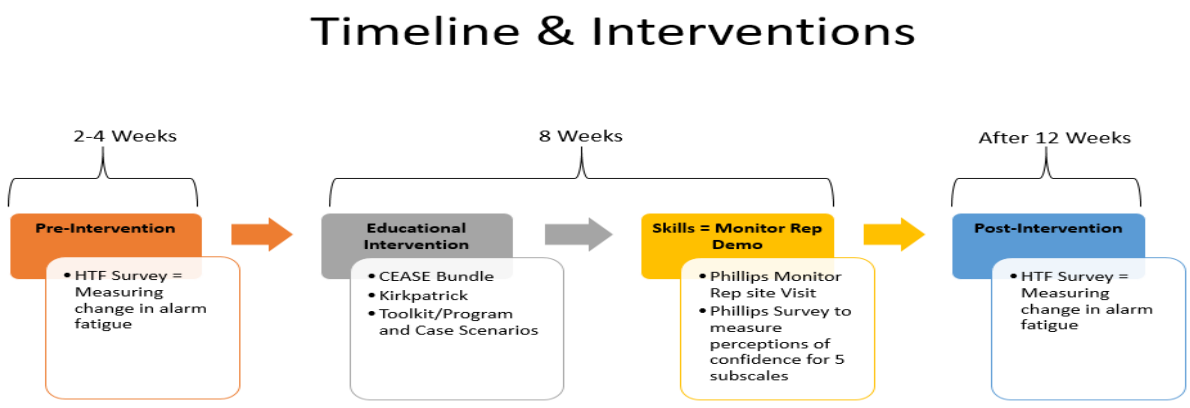
In conjunction with the CEASE bundle implementation, the CEASE bundle audit tool was also utilized to assess the level of compliance with the bundle and ensured the "alarm check" process was being performed by the nurses. This was done by active rounding by the DNP student using the CEASE audit tool. The Kirkpatrick Model was used as a guide to study the nurse's reaction, learning, behavior, and results of implementing the bundle into practice.

For the skills portion of the intervention, the DNP student met with two of the Philips monitor representatives, the ICU clinical nurse specialist, the ICU nurse educator, ICU nurse administrator, and two informatics specialists to assess the needs of the SICU and review the Philips monitor competency assessment checklist. The Philips monitor representative then visited the unit and conducted educational drop-in sessions in an empty patient room with the monitor over the span of two days from 0630 until 1900. The Philips representative reviewed common patient displays, alarm parameters, red versus yellow alarms, and ways to troubleshoot the monitor. The Philips monitor competency assessment tool, created by Philips et al. (2020), was distributed after the Philips monitor in-service and assessed for improved competency and confidence among CCNs associated with using the Philips monitors.

Following the eight-week intervention phase, the post-intervention HTF clinical alarms survey was redistributed to the SICU nurses and assessed for improvement in clinical alarm management strategies and alarm fatigue. The post-intervention survey also included two additional questions to measure the effectiveness of the alarm management bundle and whether the nurses found it beneficial to incorporate into practice. The findings were then analyzed to determine project success and the results were presented to the unit. Included below is a visual timeframe of the interventions.

Figure 3

Timeline & Interventions



Study of the Intervention

Healthcare Technology Foundation (HTF) Clinical Alarms Survey

The HTF clinical alarms survey (See Appendix D) was created by the Healthcare Technology Foundation in 2011 to improve and research alarm related issues in healthcare. In 2016, the original HTF survey was reviewed and revised by seven HTF board members, all experts in alarm management. The HTF survey received face and content validity during this process and problematic questions from the 2011 survey were excluded in the 2016 survey. The

HTF clinical alarms survey focused on identifying perceptions of clinical alarms, the occurrence of alarm associated events, improvement measures, and action priorities (Malito, 2016). The survey measured attitudes and practices towards clinical alarms pre and post project intervention.

Each question had the option to *strongly agree*, *agree*, *be neutral*, *disagree*, *strongly disagree,* or answer *yes, no, or not sure* to the proposed question or statement. The results were then analyzed and presented as a percentage to easily interpret the results using descriptive statistics to measure the findings. In addition, four demographic questions were asked at the beginning of the survey to gather information on the number of years as a registered nurse, the number of years working in a critical care unit, the number of years working in the SICU, and if the nurse primarily worked day or night shift. In the post-intervention HTF clinical alarms survey, the DNP student added two additional questions to assess the effectiveness of the bundle in reducing alarm fatigue and whether the nurse would continue to use the bundle in their nursing practice. The survey was not mandatory but highly encouraged with the goal completion rate at 70%.

Philips Monitor Confidence and Competency Assessment Tool

The Philips monitor competency and skills assessment tool (See Appendix E) was originally created in 2017 by Sowan et al. and was later revised in 2020 by Philips et al. This was the first study to create and test a list of physiologic monitor competencies. The survey was validated by 13 expert ICU nurses and originally included five subscales with 59 rated items. The first four subscales, admission, discharge and transfer patient, hardware and connectivity, alarm management, and appropriate monitoring were included in the 2020 revised version. However, the fifth subscale, advanced functions, was excluded due to infrequency of use. Out of the original 59 rated items, 28 were included for the purpose of this QI project. The nurses who

attended the session filled out the tool following the in-service training sessions to assess competency and confidence associated with using the monitor. The nurses rated each subscale as confident, neutral, not confident, and checked off whether the skill was met or not.

Active Auditing During Rounds

In order to monitor adherence to the CEASE bundle during the project, the DNP student conducted active rounds during change of shift to audit whether the nurses were incorporating the alarm check process into practice. This time was also used to evaluate how the intervention was helping or hindering the change of shift flow. The DNP student answered all questions and concerns during this time and addressed any areas for improvement. To streamline the audit process, the CEASE alarm management audit tool (See Appendix C), was utilized. The student analyzed each category of the CEASE bundle to include communication, electrodes, appropriateness, setup, and education to assess for compliance.

Measures

Project findings were measured based on the pre and post intervention results from the HTF clinical alarms survey and assessed for reduction in alarm fatigue. The Philips monitor confidence and competency assessment tool assessed confidence and competency associated with managing the physiologic monitors. The HTF clinical alarms survey was broken down into seven groups. The groups included nuisance alarms, experience with alarm systems, alarm notification, smart alarms, institutional requirements, clinical alarms management improvements, and adverse events. Each section gained insight into the specific area of focus and measured alarm fatigue and management skills pre and post project implementation. The Philips monitor confidence and competency assessment tool focused on four different subscales, which include admission, transfer and discharge, hardware and connectivity, alarm management and

appropriate monitoring. For each statement, the nurse either answered confident, neutral, or not confident. After the educational in-service was provided, the nurses were checked off on the skills met during the training.

Additionally, active auditing during rounds was completed by the DNP student to assess whether the "alarm check" was being performed during nurse handoff. This time was also utilized to measure the level of adherence to the CEASE bundle and whether the nurses on the unit found it to be effective in improving alarm management skills, increasing patient safety, and reducing alarm fatigue. In summary, the HTF clinical alarms survey measured alarm fatigue and management pre- and post-intervention. The Philips monitor confidence and competency and assessment tool assessed for confidence, competency, and skills associated with navigating the actual monitoring device, and the auditing tool established project adherence during the intervention and identified areas for practice improvement.

Analysis

Descriptive Statistics

All statistical analysis was conducted using Intellectus Statistics software (2019), SAS, R, or SPSS. Nominal and ordinal level variables were described using frequencies, mode, and percentages, and included whether the nurse primarily worked day or night shift (See Table 1). For the interval and ratio variables, the following descriptive statistics were calculated: sum, frequency, mean, median, mode, standard deviation, variance, minimum, maximum, range, interquartile range, standard error of the mean, skewness, and kurtosis (See Table 1). Interval and ratio variables included secondary analysis and were conducted at the discretion of the DNP lead and project team.

To evaluate Specific Aim 3 and corresponding process Goals A-C, the HTF Survey completion rates, Alarm Bundle Inservice Training rates, and Alarm Monitor Inservice rates were analyzed and summarized using descriptive statistics to determine intervention process fidelity. Findings from the Philip's Monitor confidence assessment tool were described using descriptive statistics appropriate for nominal variables. For the interval/ratio variables noted in Table 1, the following descriptive statistics were calculated: sum, frequency, mean, median, mode, standard deviation, variance, minimum, maximum, range, interquartile range, standard error of the mean, skewness, and kurtosis. Interval/ratio variables included:

- HTF survey completion,
- alarm management bundle in-service,
- alarm management in-service by vendor representative,
- number of years as a registered nurse,
- number of years working in a critical care unit, and
- number of years working in the SICU.

Secondary analysis was conducted at the discretion of the DNP lead and project team as appropriate to further evaluate process outcomes.

Table 1

Demographic & Descriptive Variables

Demographic or Descriptive Variables	Level of Measurement	Categories	Descriptive Statistical Procedures
Philip's Monitor Confidence	Nominal	Confident, Neutral, Not Confident	Mode, percentage, and frequency
HTF Survey completion	Ratio	0 or >	Sum, Frequency, Mean, Median, Mode, Standard deviation, Variance, Minimum, Maximum, Range,

(Specific Aim 3: Process Goal A)			Interquartile Range, Standard Error of the Mean (or *S.E. Mean*), Skewness, and Kurtosis
Alarm Management Bundle In-service *(Specific Aim 3: Process Goal B)*	Ratio	0 or >	Sum, Frequency, Mean, Median, Mode, Standard deviation, Variance, Minimum, Maximum, Range, Interquartile Range, Standard Error of the Mean (or *S.E. Mean*), Skewness, and Kurtosis
Alarm Monitor In-service by Vendor Representative *(Specific Aim 3: Process Goal C)*	Ratio	0 or >	Sum, Frequency, Mean, Median, Mode, Standard deviation, Variance, Minimum, Maximum, Range, Interquartile Range, Standard Error of the Mean (or *S.E. Mean*), Skewness, and Kurtosis
Number of years as a Registered Nurse.	Interval/Ratio	Number	Sum, Frequency, Mean, Median, Mode, Standard deviation, Variance, Minimum, Maximum, Range, Interquartile Range, Standard Error of the Mean (or *S.E. Mean*), Skewness, and Kurtosis
Number of years working in a Critical Care Unit.	Interval/Ratio	Number	Sum, Frequency, Mean, Median, Mode, Standard deviation, Variance, Minimum, Maximum, Range, Interquartile Range, Standard Error of the Mean (or *S.E. Mean*), Skewness, and Kurtosis
Number of years working in the SICU.	Interval/Ratio	Number	Sum, Frequency, Mean, Median, Mode, Standard deviation, Variance, Minimum, Maximum, Range, Interquartile Range, Standard Error of the Mean (or *S.E. Mean*), Skewness, and Kurtosis
Primarily works day or night shift	Nominal	Day Night	Mode, percentage, and frequency

Inferential Data Analysis

To evaluate *Specific Aims 1-2* and corresponding quantitative QI project outcome questions and goals, independent sample *t*-tests were conducted to assess if differences exist for self-reported alarm fatigue and alarm management competency pre- and post-intervention (See Table 2). An independent samples *t*-test was the appropriate statistical test when the purpose of research was to assess if differences exist on a continuous (interval/ratio) dependent variable by a dichotomous (2 groups) independent variable.

The assumptions of normality and homogeneity of variance were assessed. Normality assumes that the scores are normally distributed (bell-shaped) and was assessed using the one-sample Shapiro-Wilk test (Razali & Wah, 2011). Homogeneity of variance assumes that both groups have equal variances and was assessed using Levene's test for equality of variances (Levene, 1960). If Levene's test for equal variance indicated that equal variances cannot be assumed ($p < .05$), a Welch's t-test was used instead of the student's t-test, which is more reliable when the two samples have unequal variances (Ruxton, 2006). The *t*-test was two-tailed with the probability of rejecting the null hypothesis when it was true set at $p < 0.05$. This ensures a 95% certainty that the differences did not occur by chance.

The Mann-Whitney *U* test was conducted if the data were skewed and not normally distributed, or if the data did not meet the assumptions of parametric testing. The Mann-Whitney U test is the non-parametric equivalent to the independent *t*-test (Conover & Iman, 1981) and the appropriate analysis to compare differences that come from the same population when the dependent variable is ordinal or continuous. Given the non-parametric nature of this statistical analysis, there are no assumptions. The Mann-Whitney two-sample rank-sum test can be

conducted when the assumptions of the independent samples *t*-test (such as normality) are violated.

The Mann-Whitney U test compared the number of times a score from one sample was ranked higher than a score from the other sample. The scores from both samples were ranked together; rank 1 was used for the lowest score, rank 2 for the next lowest score, and so on. When scores have the same value, a tie was determined. Each of the tied scores was then assigned the same ranking. The scores were ranked, and those ranks were added together and then divided by the number of scores. Once the data was ranked, calculations were carried out on the ranks to determine the *U* statistic, a value used to obtain the *p*-value by computing the *z*-score. A significance level of 0.05 was used to determine if there were significant differences on the dependent variable between the levels of the independent variable.

Table 2

Inferential Statistics and Variables

Study Variable (Dependent Variable)	Level of Measurement	Descriptive Statistical Procedures	Inferential Statistical Procedures
Self-Reported Alarm Fatigue *(Specific Aim 1: Outcome Goals A & B)*	Interval/Ratio	Sum, Frequency, Mean, Median, Mode, Standard deviation, Variance, Minimum, Maximum, Range, Interquartile Range, Standard Error of the Mean (or *S.E. Mean*), Skewness, and Kurtosis	Independent *t*-Test or Mann Whitney U

Ethical Considerations

All the data from the surveys and active auditing were kept confidential and followed the guidelines of the Jacksonville University IRB and project site policy and procedures. The DNP student did not obtain any patient information and only used general, nonidentifying nursing

demographic variables. Since participating in the QI project was not mandatory and nurses were not specifically identified, informed consent did not need to be obtained before project initiation. However, a survey cover sheet explaining the project and survey collection process was included with each survey, stating that the nurse agreed to participate in the study if the survey was completed. Therefore, all participants in the study remained anonymous and privacy was ensured. Based on the updated COVID-19 guidelines, the objectives of the project met the IRB criteria since the project was a nurse-focused quality improvement project and patient interaction was not necessary. In addition, IRB approval was necessary and obtained by completing the online certification and research project application. The project proposal was submitted to the IRB and adjustments were made according to IRB recommendations until the project was approved for implementation. Lastly, project data was stored in a password-protected spreadsheet and the OneDrive folder was only accessible by the DNP student, DNP chair, and statisticians.

Results

Demographic Descriptive Statistics

All demographic variables were analyzed using descriptive statistics via Intellectus Statistics software (2019), SAS, or SPSS. Seventy nurses completed the pre-Healthcare Technology Foundation (HTF) Clinical Alarms Survey, while 60 completed the post survey. Twenty participants returned the Phillips Monitor Confidence instrument following the monitor training.

For both pre- and post-groups, the most frequently observed category of number of years working in the SICU was 0-2 years (pre $n = 40$, 57.14%; post $n = 35$, 58.33%). However, the most frequently observed category of number of years as a Registered Nurse was 6-10 years ($n =$

19, 27.14%) for the pre-group, and 0-2 years (n = 16, 26.67%) for the post-group of nurses. For both the pre- and post-group of nurse participants, Night Shift had a slightly larger representation of approximately 5-7% (pre n = 40, 57.14%; post n = 33, 55.00%). The most frequently observed category of Number of years working in a Critical Care Unit was 0-2 years for both the pre- (n = 22, 31.43%) and post-groups (n = 26, 43.33%).

Prior to running inferential analysis, internal consistency reliability testing was performed on the scale items included in the Healthcare Technology Foundation (HTF) Clinical Alarms Survey. A Cronbach's alpha coefficient of .97 resulted, indicating excellent reliability. Table 3 presents the results of the reliability analysis.

Table 3

Reliability Table for the Healthcare Technology Foundation (HTF) Clinical Alarms Survey

Scale	No. of Items	α	Lower Bound	Upper Bound
HTF	16	.97	.97	.98

Note. The lower and upper bounds of Cronbach's α were calculated using a 95.00% confidence interval.

Specific Aim Analysis

Specific Aim #1

Specific Aim #1 sought to evaluate two goals. Outcome Goals A-B sought to determine if there was a statistically significant decrease in self-reported alarm fatigue as measured by the HTF clinical alarms survey post-project intervention. Eighty-two percent (n=49) reported that the use of the CEASE bundle helped to decrease their alarm fatigue. Sixteen percent (n=10) reported that they were not sure, and one participant reported that it did not decrease their alarm fatigue. Therefore, Specific Aim #1 was met.

Specific Aim #2

Specific Aim 2 served as a process measure to evaluate intervention implementation fidelity by way of SICU nursing staff participation in the project's educational and in-service interventions. For Process Goal A, the project aimed to have a minimum of 70% the SICU nurses complete the HTF clinical alarms survey. Approximately 115 full time nurses worked on the unit pre- and post-project intervention. Thus, approximately 61% (n=70) completed the pre-project and 52% (n=60) completed the post-project HTF surveys. Therefore, the goal of 70% was not met. For Process Goal B, the project aimed to have a minimum of 70% of the SICU's nursing staff complete the alarm management bundle training, 1:1 discussion by the DNP Project Lead or the Philips monitor representative. This goal was met at 100%. Finally, Process Goal C aimed to achieve a minimum of 70% of the SICU's nursing staff who successfully attended the alarm monitor in service training via the Philips monitor representative and also complete the Philips monitor competency check off tool. Twenty, or 17%, completed the in-service which was in part due to the availability of the Phillips monitor representative. Therefore, this goal was not met.

Specific Aim #3

The goal of Specific Aim #3 was to assess for nurse implementation of the CEASE bundle and alarm check process into practice. At baseline, there was no unit requirement to perform an alarm check with the oncoming nurse at shift change. Therefore, alarm settings, parameters, and special patient considerations were not previously discussed between nurses. During project implementation, the alarm check process was introduced during shift change and was performed during the review of the patient's hemodynamics. At this point, the nurses reviewed alarms, set patient specific parameters, and ensured the proper safety alarms, such as ventricular arrythmias, apnea, and asystole alarms were never turned off. This was introduced

into practice to review the patient specific settings and ensure patient safety was kept at the highest priority.

In addition, implementation of the CEASE bundle into practice was assessed to ensure nurses were utilizing the bundle. Prior to the DNP project, there was no unit-specific or institution required education on best practice guidelines for alarm management strategies and skills. Therefore, the provided education and implementation of the CEASE bundle served as the first evidence-based practice alarm management resource to guide nursing practice in the SICU.

For Process Goal A, all the nurses partaking in the project education, at least 80% were satisfied with the presented education and learning objectives were met. Therefore, the goal of at least 80% was met and exceeded. For Process Goal B, active auditing rounds were used to ensure at least 60% of nurses adhered to the alarm check process and implemented the CEASE bundle into practice. Active auditing was conducted by the DNP student using the CEASE bundle audit tool during change of shift for about one week. Over the course of the project, 74 nurses were observed and questioned regarding their adherence to the implemented CEASE alarm management bundle and alarm check process.

Target of 60% Adherence. Out of the 74 nurses who were audited during the DNP project rounds, 40 of the observed nurses were performing the alarm check, utilizing the bundle, and adhering to the five categories of the CEASE bundle (communication, electrodes, appropriate, set up and education). Therefore, 54% of the nurses were compliant with implementing the bundle and performing the alarm check process. Thus, this process goal was not met. Despite this finding, 83% (n=50 out of 60) reported that the CEASE bundle was beneficial to their nursing practice and that they were using the bundle in practice.

Specific Aim 4

Specific Aim 4 sought to evaluate improvement in staff alarm management competency (Outcome Goal A) and confidence (Outcome Goal B). A two-tailed independent samples *t*-test was conducted to examine whether the means of the scale variables included in the HTF Survey significantly improved from pre- to post-intervention. Some items are reversed scored whereby a decrease in the means notes improvement. Because the pre- and post-HTF survey data were not normally distributed, the Mann Whitney U (non-parametric alternative to the independent samples *t*-test) was performed. A two-tailed Mann-Whitney two-sample rank-sum test was conducted to examine whether there were significant differences in each of the HTF scale variables as noted in Table 4.

Statistically Significant HTF Findings. The following HTF scale item results of the two-tailed Mann-Whitney U test was significant based on an alpha value of .05 from the pre-group measure to the post-group measure:

- Properly setting alarm parameters is complex
- Newer monitoring systems have solved problems
- There have been times when alarms were missed
- Clinical staff is sensitive to alarms and respond quickly
- Smart alarms would be effective to use for reducing false alarms
- Smart alarms would be effective to improve clinical response to alarms
- Clinical policies and procedures regarding alarm management are used in my facility
- The Joint Commissions National Patient Safety goal on alarm management has reduced adverse patient events.

Properly Setting Alarm Parameters is Complex. For the "Properly setting alarm parameters is complex" item, the result of the two-tailed Mann-Whitney *U* test was significant

based on an alpha value of .05, $U = 2510$, $z = -2.12$, $p = .034$. The mean rank for group pre-group was 71.36 and the mean rank for the post-group was 58.67. This suggests that the distribution of "properly setting alarm parameters is complex" for pre-group was significantly different from the distribution of "Properly setting alarm parameters is complex" for the post-group. The median for pre-group (*Mdn* = 2.50) was significantly larger than the median for post-group (*Mdn* = 2.00). Findings suggest that nurses perceived that properly setting the alarm settings was less complex following the project interventions.

Newer Monitoring Systems Have Solved Problems. The result of the two-tailed Mann-Whitney *U* test was significant based on an alpha value of .05, $U = 1647$, $z = -2.30$, $p = .022$ for the HTF item "newer monitoring systems have solved problems." The mean rank for pre-group was 59.03 and the mean rank for post-group was 73.05, suggesting that the distribution for pre-group was significantly different from the distribution of the post-group. The median for pre-group (*Mdn* = 3.00) was significantly lower than the median for pos-group (*Mdn* = 3.00). Findings suggest that nurses perceived that newer monitoring systems had solved problems following the project interventions.

There Have Been Times When Alarms Were Missed. The result of the two-tailed Mann-Whitney *U* test was significant based on an alpha value of .05, $U = 3601$, $z = -7.58$, $p < .001$. The mean rank for the pre-group was 86.94 and the mean rank for post-group was 40.48. This suggests that the distribution of "There have been times when alarms were missed" for pre-group was significantly different from the distribution of post-group. The median for the pre-group (*Mdn* = 4.00) was significantly larger than the median for post-group (*Mdn* = 2.00). Findings suggest that nurses perceived fewer instances of missing alarms post project interventions.

Clinical Staff Is Sensitive to Alarms and Respond Quickly. The result of the two-tailed Mann-Whitney *U* test was significant based on an alpha value of .05, $U = 1699$, $z = -2.17$, $p = .030$. The mean rank for the pre-group was 59.77 and the mean rank for the post-group was 72.18. This suggests that the distribution of "clinical staff is sensitive to alarms and respond quickly" for the pre-group was significantly different from the distribution of the post-group. The

median for pre-group (*Mdn* = 4.00) was significantly lower than the median for post-group (*Mdn* = 4.00). Findings suggest that nurses perceived improvement in clinical staff sensitivity to alarms and in their quick response post project interventions.

Smart Alarms Would Be Effective to Use for Reducing False Alarms. The result of the two-tailed Mann-Whitney *U* test was significant based on an alpha value of .05, $U = 1641.5$, $z = -2.44$, $p = .015$. The mean rank for the pre-group was 58.95 and the mean rank for the post-group was 73.14. This suggests that the distribution of "smart alarms would be effective to use for reducing false alarms" for the pre-group was significantly different from the distribution for the post-group. The median for the pre-group (*Mdn* = 4.00) was significantly lower than the median for the post-group (*Mdn* = 4.00). Findings suggest that nurses perceived smart alarms would be effective in reducing false alarms post project interventions.

Smart Alarms Would Be Effective to Improve Clinical Response to Alarms. The result of the two-tailed Mann-Whitney *U* test was significant based on an alpha value of .05, $U = 1709$, $z = -2.09$, $p = .036$. The mean rank for the pre-group was 59.91 and the mean rank for the post-group was 72.02. This suggests that the distribution of "smart alarms would be effective to improve clinical response to alarms" for the pre-group was significantly different from the distribution for the post-group. The median for the pre-group (*Mdn* = 4.00) was significantly lower than the median for the post-group (*Mdn* = 4.00). Findings suggest that nurses perceived smart alarms would be effective to improve clinical response to alarms post project interventions.

Clinical Policies and Procedures Regarding Alarm Management Are Used in My Facility. The result of the two-tailed Mann-Whitney *U* test was significant based on an alpha value of .05, $U = 1387$, $z = -3.55$, $p < .001$. The mean rank for the pre-group was 55.31 and the mean rank for the post-group was 77.38. This suggests that the distribution of "clinical policies and procedures regarding alarm management are used in my facility" for the pre-group was significantly different from the distribution for the post-group. The median for the pre-group (*Mdn* = 3.00) was significantly lower than the median for the post-group (*Mdn* = 4.00). Findings

suggest that nurses perceived improvement in the use of clinical policies and procedures regarding alarm management post project interventions.

The Joint Commission's (TJC) National Patient Safety Goal on Alarm Management Has Reduced Adverse Patient Events. The result of the two-tailed Mann-Whitney *U* test was significant based on an alpha value of .05, $U = 1728$, $z = -2.02$, $p = .043$. The mean rank for the pre-group was 60.19 and the mean rank for the post-group was 71.70. This suggests that the distribution of "The Joint Commissions National Patient Safety goal on alarm management has reduced adverse patient events" for the pre-group was significantly different from the distribution for the post-group. The median for the pre-group ($Mdn = 3.00$) was significantly lower than the median for the post-group ($Mdn = 3.00$). Findings suggest that nurses perceived that the TJC alarm management safety goal had reduced adverse events post project interventions.

Clinically Significant HTF Findings. Though not all of the HTF indicators demonstrated statistically significant improvement, several indicators did improve from baseline. For example, participants indicated a reduction in the frequency of nuisance alarms occurring from a mean rank of 69.69 pre-intervention to 60.73 post-intervention. Alarm integration and communication systems also improved from a mean rank of 63.81 to 67.47. Furthermore, background noise interfering with alarm recognition decreased from a mean rank of 68.63 to 61.85. For the item "nuisance alarms occur frequently," the mean rank decreased from 69.59 to 60.73, indicating a reduction in nuisance alarms.

Non-Significant HTF Findings. Despite improvement in 75% (n=12) of the HTF items, some items did not show improvement. None of the items showed significant decreases or worsening from pre- to post-intervention. "Nuisance alarms disrupt patient care" continued to be an issue with mean ranks slightly increasing from 62.86 to 68.58, as well as "nuisance alarms reduce trust in alarms" which increased from 61.32 to 70.38.

Outcome Goal A Summary. Overall, nursing staff participants demonstrated improved alarm management competency which resulted in significant improvements in their perceptions of alarm functionality, settings, response, and policy adherence. Therefore, Specific Aim #4 Outcome Goal A was met.

Table 4

Two-Tailed Mann-Whitney Test for HTF Scale Variables by Pre or Post

	Mean Rank				
Variable	Pre	Post	*U*	*z*	*p*
Nuisance alarms occur frequently	69.59	60.73	2,386.00	-1.60	.110
Nuisance alarms disrupt patient care	62.86	68.58	1,915.50	-0.97	.333
Nuisance alarms reduce trust in alarms	61.32	70.38	1,807.50	-1.49	.136
Properly setting alarm parameters is complex	71.36	58.67	2,510.00	-2.12	.034
Newer monitoring systems have solved problems	59.03	73.05	1,647.00	-2.30	.022
Alarms on my floor are adequate to alert staff	66.39	64.46	2,162.50	-0.38	.707
There have been times when alarms were missed	86.94	40.48	3,601.00	-7.58	< .001
Clinical staff is sensitive to alarms and respond quickly	59.77	72.18	1,699.00	-2.17	.030
When a number of devices are used with a patient	65.86	65.08	2,125.50	-0.13	.900
Background noise has interfered with alarm recognition	68.63	61.85	2,319.00	-1.09	.275
Alarm integration and communication systems	63.81	67.47	1,981.50	-0.62	.537
Central alarm management staff is helpful	67.91	62.68	2,269.00	-0.83	.404
Smart alarms would be effective to use for reducing false alarms	58.95	73.14	1,641.50	-2.44	.015
Smart alarms would be effective to improve clinical response to alarms	59.91	72.02	1,709.00	-2.09	.036
Clinical policies and procedures regarding alarm management are used in my facility	55.31	77.38	1,387.00	-3.55	< .001
The Joint Commissions National Patient Safety goal on alarm management has reduced adverse patient events	60.19	71.70	1,728.00	-2.02	.043

Outcome Goal B. Specific Aim #4, Outcome Goal B sought to increase nursing staff confidence in alarm management competency by 60% following educational seminars and implementation of a unit wide, evidence-based alarm management bundle. The Philip's monitor confidence and competency assessment tool focused on four different subscales, which included a) admission, transfer, and discharge (PC1-PC3); hardware and connectivity (PC4-PC5); c) alarm management (PC6-PC17); and d) appropriate monitoring (PC18-PC28). For each statement, the nurse either answered confident, neutral, or not confident. Twenty nurses completed and returned the survey. For all items, with the exception of PC2 and PC3,

participants indicated confidence in performing the competency item as noted in Table 5. For the "edit patient information mismatch" item, 95% (n=19) indicated confidence with 5% (n=1) indicating neutral. For the "resolve patient information mismatch" item, 90% (n=18) indicated confidence, 5% (n=1) indicated neutral, and 5% (n=1) indicated that they were not confident. Overall, more than 60% of respondents indicated confidence and therefore Outcome Goal B was met. Significance testing was not possible as participants did not complete the assessment prior to the project intervention.

Table 5

Philip's Monitor Confidence Descriptive Results

Variable	Confident	Neutral	Not Confident
PC1. Admit, transfer and discharge patient from central and beside monitors appropriately	20	0	0
PC2. Edit patient information after admission	19	1	0
PC3. Resolve patient information mismatch	18	1	1
PC4. Connect monitor cables appropriately	20	0	0
PC5. Identify monitors hardware components and connectors	20	0	0
PC6. Silence alarms, pause alarms, and cancel the pause	20	0	0
PC7. Know different types of parameters display and the meaning of the wave	20	0	0
PC8. Differentiate the priority and meaning of the alarm	20	0	0
PC9. Change alarm volume easily	20	0	0
PC10. Choose and change the source of an alarm appropriately	20	0	0
PC11. Change alarm limits safely and appropriately	20	0	0
PC12. Identify and differentiate the priority and meaning of all alarm messages based on alarm indicators	20	0	0
PC13. Acknowledge and correct alarm messages	20	0	0
PC14. Differentiate the source of each alarm	20	0	0
PC15. Customize default settings to patient specific	20	0	0
PC16. Troubleshoot technical alarm messages	20	0	0
PC17. Eliminate redundant alarms when changing default settings	20	0	0
PC18. Place electrodes appropriately and describe best practices in management	20	0	0
PC19. Change the NBP measurement interval and modes	20	0	0
PC20. Store and send the 12 lead ECG to the central monitor	20	0	0
PC21. Zero the pressure transducer	20	0	0
PC22. Put monitor into standby mode and resume	20	0	0
PC23. Select appropriate invasive pressure label for monitoring	20	0	0
PC24. Change the size of a waveform	20	0	0
PC25. Select optimal SpO2 measurement site	20	0	0
PC26. Recognize elements and purpose of using monitors screen keys	20	0	0
PC27. Pick best primary and secondary leads for paced and non-paced patients	20	0	0
PC28. Navigate the different monitors screens easily	20	0	0

Specific Aim #5

The goal of Specific Aim #5 was to assess for an overall improvement from baseline in alarm management practices and processes, and whether those alarm management practices and processes were being implemented. At baseline, there was no prior method to measure nurses alarm management practices and processes. Additionally, there was no formal alarm management education in place. The entirety of the nurse's alarm management education occurred during the orientation period, which lasted anywhere from six weeks to six months, and was conducted by the orientees assigned preceptor. This variability in education resulted in inconsistencies in alarm management practices amongst nurses working in the SICU. Therefore, a streamlined educational approach to alarm management practices and processes was warranted.

Qualitative Process Goal A. The first qualitative process goal sought to measure an overall improvement in alarm management practices and processes as directly observed and self-reported during shift huddles, staff meetings, and/or rounding via qualitative interviews or small group discussion in accordance with the alarm management bundle.

Observational and Self-Reported Improvement in Alarm Management Practices and Processes. From small group discussions, active rounding and educational seminars, the DNP student was able to conclude that there was an overall improvement in alarm management practices and processes as reported and observed from nursing practice. Therefore, this goal was met.

Qualitative Process Goal B: The second qualitative process goal assessed whether the alarm management practices and processes were successfully implemented as qualitatively measured via direct observation (>60% of the time observed) and self-reported during shift

huddles, staff meetings, and/or rounding via qualitative interviews or small group discussion in accordance with the alarm management bundle.

Alarm Management Practices and Processes Successfully Implemented. Active rounding by the DNP student assessed for observational implementation of alarm management practices and processes. As mentioned in Specific Aim #3, the observed implementation rate was 54%. Therefore, this process goal of achieving 60% compliance via observation was not met. However, based on nurse-to-nurse discussion, staff meetings, and shift huddles, nurses admitted to utilizing the CEASE bundle at least once throughout the shift to improve alarm management practices and processes and comply with the project bundle. Therefore, this goal was met.

Summary

Based on the demographic descriptive results, night shift had a slightly greater representation of participants than day shift, and the majority of surveyed nurses had only worked in a Critical Care Unit and/or the SICU for 0-2 years in both the pre- and post- groups. The target survey completion rate of 70% out of the 115 total nurses was not met since the actual compliance rate was 61% pre-survey and 52% post-survey. Additionally, only 17% of the nurses were able to complete the Philips monitor in-service training sessions due to limited availability from the Philips representative. However, 95% of the nurses who attended the Philips monitor training indicated confidence in each section of the Philips Monitor Confidence and Competency Assessment tool post in-service training. Furthermore, 100% of the nurses received formal education on the CEASE alarm management bundle from the DNP student during the two mandatory staff meetings.

Following the project interventions, nurses found setting alarm parameters was less complex, staff was sensitive to alarms and responded quickly, there were fewer instances of

alarms being missed, smart alarms would be effective in reducing false alarms and would improve clinical response time, policies and procedures regarding alarm management were effectively used in the facility, and TJC's alarm management safety goal reduced adverse events. Although not all of the HTF indicators demonstrated statistically significant improvement, several indicators did improve from baseline. Participants indicated a reduction in the frequency of nuisance alarms by 9%, and background noise interfering with alarm recognition decreased by 7%. For the item "nuisance alarms occur frequently," the mean rank decreased by 9%, indicating a reduction in nuisance alarms. Despite improvement in 75% of the HTF items, some items did not show improvement. None of the items showed significant decreases or worsening from pre- to post-intervention. "Nuisance alarms disrupt patient care" continued to be an issue with mean ranks slightly increasing by 6%, as well as "nuisance alarms reduce trust in alarms" which increased by 9%. However, 82% of nurses reported that the use of the CEASE bundle helped to decrease their alarm fatigue, and 83% of nurses found the CEASE bundle was beneficial to their nursing practice and would continue to utilize the bundle. Therefore, alarm management competency among SICU nurses increased and alarm fatigue decreased.

Interpretation

As previously mentioned, the majority of nurses who participated in the study were either new to the ICU setting, new to the SICU, or new to the field of nursing based on the post- group results. This indicated that there was a lack of experienced nurses on the unit who may have already been efficient in navigating the Philips monitors and had established alarm management practices. Therefore, the DNP project was conducive to less experienced nurses who would greatly benefit from alarm management education. This could have been a contributing factor to project success since the CEASE bundle was reported to be helpful and effective in reducing the

severity of alarm fatigue. In addition, since there was no previous alarm management protocol or education in place, the new graduate nurses on the unit lacked proper education on the Philips monitors before the QI project. In the past, nurses learned alarm management techniques while on orientation and gained more experience with time. Recommendations were made from staff to incorporate formal education surrounding the Philips monitors and alarm management practices in the future and are discussed under conclusions.

Furthermore, while the Philips monitor in-service training was a success based on the nurses who were able to participate, a large majority of nurses were unable to attend due to time constraints placed on the Philips representative. However, 95% of the nurses in attendance proved competent and confident during the sessions. Therefore, this would be beneficial to continue in the future. Overall, implementing the CEASE bundle proved to improve nurses alarm management practices, perceptions, and attitudes on a unit wide level. Alarm management competency was brought to light and problems were addressed for practice improvement. The high level of facility and unit support for the project stimulated positive changes hospital wide regarding alarm management confidence, competency, education, and safety.

Limitations

There were a few limitations to note during the project. The first limitation was completing the project during the height of the pandemic during the Omicron variant wave. Many nurses were absent from work during this time period in two-week increments if infected with COVID or left the SICU to partake in travel nursing. Due to these factors, the unit was extremely short-staffed. Therefore, stress from the pandemic, being understaffed, and training several new graduate nurses could have limited the survey response rate and participation in the in-service Philips monitor training sessions. Another limitation worth noting was the short time

frame the Philips monitor representative was able to complete the in-service training sessions on the unit. The representative was only allotted two days for training and was limited to the hours of 0630 to 1900. Due to this constriction in time, almost all the night shift nurses were unable to make the in-service training sessions, and very few day shift nurses were able to attend due to the high acuity level of patients on the unit requiring one-to-one attention.

Conclusions

Significance and Usefulness

The Joint Commissions ongoing goal of improving clinical alarm safety in 2022 remains a top priority nationwide. Therefore, implementation of the evidence-based practice CEASE alarm management bundle was warranted and proved to be effective in reducing SICU nurses' level of alarm fatigue and improved alarm management practices. By improving alarm management competency and establishing alarm management policies with continued education, clinical alarm safety was upheld. While alarm fatigue may not ever completely subside, there are areas for improvement with the use of smart alarms and remote patient monitoring devices, as evidenced from the study results. This will continue to be an ongoing process. However, the project interventions showed a statistically significant improvement in alarm management confidence and competency, and is therefore, useful to the overall goal of reducing alarm fatigue and improving clinical alarm safety through increased alarm management competency among nurses.

Sustainability

Coincidently, during the time the student contacted the ICU nurse educators, nurse manager, and ICU nurse administrator regarding the Philips monitor representatives visiting the unit to perform in-service training sessions for the SICU nurses, a patient event associated with a

missed alarm occurred on a different unit. Therefore, the nurse administrators were thrilled that the DNP student organized the discussion to meet with the Philips representatives and formulate an action plan following the event. After the meeting, the student was asked to assist the assigned administrators responsible for creating the alarm management and educational initiative hospital wide. Therefore, while the results of this project were confined to the SICU, there was a great need for education on proper evidence-based alarm management practices throughout the hospital.

Furthermore, the QI project proved sustainable given the great support from leadership and staff, as well as a great number of nurses being new graduate nurses or being new to the unit. Formal education will begin during the required hemodynamics course as a result of the QI project. Highly qualified SICU nurses will present the hemodynamic education and simultaneously review the monitors to include changing waveforms, setting patient specific parameters, addressing clinical alarms, and navigating the monitor appropriately and safely. This will streamline the education process surrounding alarm management and allow hands-on training with the monitors outside of the orientation process. In conclusion, the sustainability of this project far exceeded expectations given the tremendous support from leadership and the overall need for this QI project at the facility and unit level.

Dissemination of Findings

The project findings were disseminated through an in person, oral presentation to faculty, family, and friends at Jacksonville University. The DNP student's faculty chair was present along with other graduate nursing staff. Results of the project were also shared with select administration at the project location. A written manuscript was submitted to the Critical Care

Nurse journal in publication with the American Association of Critical Care Nurses (AACN). The final DNP scholarly paper was submitted to the respected repositories.

Project Funding

The project was funded solely by the DNP student. The DNP student paid $75 dollars to use the CEASE bundle and CEASE bundle audit tool. Also, a donation of $10 dollars was made to HTF to use their 2016 HTF Clinical Alarms Survey. The DNP student purchased two folders and a large container for survey collection, totaling $15. There were no expenses associated with printing the surveys or displaying the CEASE bundle around the unit. The facility covered any cost associated with having the Philips monitor representative visit the unit to provide in-service training on the monitors, as well as the salary educational dollars for the nurses to participate during regular working hours.

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Appendix A

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Licensed Content Title	Research Outcomes of Implementing CEASE: An Innovative, Nurse-Driven, Evidence-Based, Patient-Customized Monitoring Bundle to Decrease Alarm Fatigue in the Intensive Care Unit/Step-down Unit
Licensed Content Author	Carmencita Lorenzo Lewis and Cynthia A. Oster
Licensed Content Date	May 1, 2019
Licensed Content Volume	38
Licensed Content Issue	3
Type of Use	Dissertation/Thesis
Requestor type	University/College
Sponsorship	No Sponsorship
Format	Print and electronic
Will this be posted online?	Yes, on a secure website
Portion	Figures/tables/illustrations
Number of figures/tables/illustrations	3
Author of this Wolters Kluwer article	No
Will you be translating?	No
Intend to modify/change the content	No
Title	Improving Clinical Alarm Fatigue and Job Satisfaction Among Critical Care Nurses by Implementing a Unit Based Alarm Management Bundle

Institution name	Jacksonville University
Expected presentation date	Jul 2021
Portions	Tables 2,3 & 5
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Appendix B

CEASE Bundle

Bundle Component	Description
C: Communication	● Communicate with colleagues
	● Pause or suspend alarms when performing care activities that create nonactionable alarms
E: Electrodes	● Electrocardiogram (ECG)
	○ Change ECG electrodes daily or more often if needed
	○ Place leads correctly
	○ Provide proper skin preparation
	▪ Excessive hair should be clipped AND
	▪ Clean skin with soap and water; dry with a towel before electrode application
	● Pulse oximeter
	○ Change pulse oximetry sensors as needed
	○ Check skin integrity under pulse oximetry sensor
A: Appropriate	● Collaborate with physician and other interprofessional partners
	○ Is ECG, SpO_2, CVP, PAP, $EtCO_2$, etc, monitoring clinically indicated for the patient?
	○ Is there an appropriate order?
	○ Choose appropriate monitoring parameters
	○ Discontinue monitoring devices when monitoring no longer necessary
S: Setup	● Customize alarm parameters for individual patient per institutional policy and procedure developed by interprofessional team
	○ Customize heart rate, blood pressure, respiratory rate, SpO_2 and PVC defaults
	○ DO NOT change alarms for ventricular tachycardia, ventricular fibrillation or asystole
	○ Set customized alarm defaults to ±10% patient baseline
	○ Set customized alarms within 1 hour of assuming care and as patient condition changes
E: Education	● Educate nursing staff on monitoring system
	● Educate nursing staff on monitoring system alarm communication algorithms

Abbreviations: CVP, central venous pressure; $EtCO_2$, end-tidal carbon dioxide; PAP, pulmonary artery pressure; PVC, premature ventricular contraction; SPO_2, peripheral capillary oxygen saturation.

DIMENSIONS OF CRITICAL CARE NURSING

Appendix C

CEASE Active Auditing During Rounds Tool

Date_____

Shift_____

OBJECTIVE: To assess individual staff nurse adherence to evidence-based monitoring practices

	Y	N	N/A
Communication • Did RN communicate and/or suspend alarms when performing care activities that create non-actionable alarms?			
Electrodes • Did RN change ECG electrodes and place correctly? • Is excessive hair clipped; skin cleaned and dried with a towel before electrode application? • Did RN check the skin under the pulse oximetry sensor and change as needed?			
Appropriate • Did RN screen the patient for monitoring appropriateness? • Did RN discontinue monitoring parameters when no longer needed?			
Setup • Did RN customize alarm parameters ±10% patient baseline within 1 hour of assuming care? • Did RN customize alarm parameters ±10% patient baseline when patient condition changed?			
Education • Does RN need more education on evidence-based monitoring practices?			

DIMENSIONS OF CRITICAL CARE NURSING

Appendix D

Demographics & HTF Clinical Alarms Survey

A. WORK-RELATED DEMOGRAPHICS

1. **Number of years as a Registered Nurse**
   - ○ 0-2 years
   - ○ 3-5 years
   - ○ 6-10 years
   - ○ 11-15 years
   - ○ 16 + years

2. **Number of years working in a Critical Care Unit**
   - ○ 0-2 years
   - ○ 3-5 years
   - ○ 6-10 years
   - ○ 11-15 years
   - ○ 16 + years

3. **Number of years working in the SICU**
   - ○ 0-2 years
   - ○ 3-5 years
   - ○ 6-10 years
   - ○ 11-15 years
   - ○ 16 + years

4. **Primarily day or night shift**
   - ○ Day shift
   - ○ Night shift

B. ALARM-RELATED INFORMATION

GROUP 1: Nuisance Alarms

Nuisance alarms include both false and non-actionable alarms. False alarms occur when there is

no valid triggering event, whereas non-actionable alarms correctly sound, but for an event for which no clinical intervention or action would be taken.

. Nuisance alarms occur frequently:

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

. Nuisance alarms disrupt patient care:

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

. Nuisance alarms reduce trust in alarms and cause care givers to inappropriately turn alarms off at times other than during setup or procedures:

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

GROUP 2: Experience with Alarm Systems

4. Properly setting alarm parameters and alerts is overly complex in existing devices:

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

5. Newer monitoring systems (e.g., less than three years old) have solved most of the previous problems we experienced with clinical alarms:

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

6. The alarms used on my floor/area of the hospital are adequate to alert staff of potential or actual changes in a patient's condition:

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

7. There have been frequent instances where alarms could not be heard and were missed:

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

8. Clinical staff is sensitive to alarms and responds quickly:

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

9. When a number of devices are used with a patient, it can be confusing to determine which device is in an alarm condition:

- Strongly agree
- Agree
- Neutral

- Disagree
- Strongly disagree

10. Background noise has interfered with alarm recognition:

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

GROUP 3: Alarm Notification

11. Does your hospital use alarm notification systems such as pagers, cell phones, or other wireless devices to communicate alarm conditions?

- Yes
- No
- Not sure

12. Alarm integration and communication systems using pagers, cell phones, or other wireless devices are useful for improving alarm management and response:

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

13. Does your institution use "monitor watchers" in a central viewing area to observe and communicate alarm conditions to caregivers?

- Yes
- No
- Not sure

14. Central alarm management staff (“monitor watchers”) responsible for receiving alarm messages and alerting appropriate staff is helpful:

- Strongly agree
- Agree

- Neutral
- Disagree
- Strongly disagree

GROUP 4: Smart Alarms

15. Does your institution use systems that employ smart alarms (e.g., where multiple parameters, rate of change of parameters, and signal quality, are automatically assessed in their entirety)?

- Yes
- No
- Not sure

16. Smart alarms (e.g., where multiple parameters, rate of change of parameters, and signal quality, are automatically assessed in their entirety) would be effective to use for reducing false alarms:

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

17. Smart alarms (e.g., where multiple parameters, rate of change of parameters, and signal quality, are automatically assessed in their entirety) would be effective to use for improving clinical response to important patient alarms:

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

GROUP 5: Institutional Requirements

18. If you are responsible for clinical alarms, have you been educated on the purpose and proper operation of alarm systems?

- Yes
- No
- Not sure

19. Is there a requirement in your institution/unit to document that the alarms are set and are appropriate for each patient?

- Yes
- No
- Not sure

20. Clinical policies and procedures regarding alarm management are effectively used in my facility:

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

GROUP 6: Clinical Alarms Management Improvements

21. Has your institution developed clinical alarm improvement initiatives over the past two years (e.g. policies and procedures, education, special projects, new technology)?

- Yes
- No
- Not sure

22. Has your institution instituted new technological solutions to improve clinical alarm safety?

- Yes
- No
- Not sure

GROUP 7: Adverse Events

23. Has your institution experienced adverse patient events in the last two years related to clinical alarm problems?

- Yes
- No
- Not sure

24. The Joint Commission's National Patient Safety Goal on Alarm Management that became effective in 2014 has reduced adverse patient events:

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

GROUP 8: Post intervention Bundle Questions

25. Did you find the CEASE Alarm Management Bundle beneficial to your nursing practice, and will you continue to utilize the bundle?

- Yes
- No
- Not sure

26. Did implementing the CEASE Alarm Management Bundle help decrease your alarm fatigue?

- Yes
- No
- Not sure

Appendix E

Phillips Monitor Confidence and Competency Assessment Tool

Item No.	Assessment items by subscale	Percent of nurses (%)			
		Confident	Neutral	Not Confident	Skill Met
1. Admit, Discharge, and Transfer Patient					
1	Admit, transfer and discharge patient from central and beside monitors appropriately				
2	Edit patient information after admission				
3	Resolve patient information mismatch (*e.g.*, between X2[a] and bed side monitor, or bedsideand central monitors)				
2. Hardware and Connectivity					
4	Connect monitor cables appropriately				
5	Identify monitors' major hardware components and connectors (SpO 2[b], NBP[c], *etc.*)				
3. Alarm Management					
6	Silence alarms, pause alarms and cancel the pause				
7	Know different types of parameters' display and the meaning of waves and information in the display (*e.g.*, arrhythmia, SpO2[b], Respiration, *etc.*)				
8	Differentiate the priority of the alarm and the meaning of the alarm message				
9	Change alarm volume easily				
10	Choose and change the source (*e.g.*, Systolic, Mean, Systolic and Me an) of an alarm appropriately (*e.g.*, pressure alarms source, NBP [c], *etc.*)				
11	Change alarm limits safely and appropriately				
12	Identify and differentiate the priority (*e.g.*, from crisis to advisory) and meaning of all physiologic alarm messages, based on visual and audible alarm indicators				
13	Acknowledge and correct alarm messages appropriately				
14	Differentiate the source of each alarm (*e.g.*, HR[e] Low alarm is from ECG[f] settings)				
15	Customize default settings to patient specific				
16	Troubleshoot common technical alarm messages (*e.g.*, Check Patient ID)				
17	Eliminate redundant alarms when changing default settings (*e.g.*, if ST[g] and STE[h] areselected, STE[h] will be redundant alarms)				
4. Appropriate Monitoring					
18	Place electrodes appropriately and describe best practices in electrode management				
19	Change the NBP[c] measurement interval and modes (manual, auto, stat)				
20	Store and send the 12-lead ECG[f] to the central monitor				
21	Zero the pressure transducer				

22	Put monitor into Standby mode and resume from Standby monitorin g				
23	Select appropriate invasive pressure label for monitoring (*e.g.*, ABP[j], ICP[k], PAP[l], Ao[m])				
24	Change the size of a waveform				
25	Select optimal SpO2[b] measurement site				
26	Recognize elements and purpose of using monitors' Screen Keys: (1) The four permanentkeys (Silence, Pause Alarms, Main Setup, Main Screen), (2) smart keys, and (3) pop-up keys				
27	Pick best primary and secondary leads for paced and non-paced patients				
28	Navigate the different monitors' screens easily (ie. different profiles)				