

Get the Beep Out: A QI Project to Decrease Nuisance Physiological Alarms in a Medical ICU

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Table of Contents

Abstract	3
Introduction and Background	4
Problem Statement	6
Purpose Statement	7
Review of Literature	8
Theoretical Model	13
Project Design	17
Implementation	19
Evaluation	30
Discussion	33
Conclusion	36
References	38
Appendix	43

Abstract

Background: Upwards of 99% of physiological alarms may not require intervention and make monitoring devices unreliable. Over time, the unreliability of monitoring devices creates desensitization and can lead to patient deaths. Alarm management is now a Joint Commission National Patient Safety Goal and ECRI Institute has named alarm hazards as the number one of the top 10 health technology hazards. Objectives: To reduce the number of nuisance physiological alarms in adult patients on the medical intensive care unit. Methods: A quality improvement process was used that included eliminating inactionable alarms from the default settings, customizing alarms, changing electrocardiography electrodes daily, and standardizing skin preparation. Results: In the medical intensive care unit, the mean number of nuisance alarms per patient per day decreased from 13 (baseline) to 3, and 81% reduction. Conclusion: Use of a bundled approach to managing alarms lessened the mean number of alarm signals in a medical intensive care unit.

Keywords: alarms, fatigue, nuisance, systems, monitoring, clinical alarms, and physiological alarms

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Introduction

The number of devices in hospitals that alarm continues to increase from six in 1983 to 40 or more in 2012 (Lukasewicz & Mattox, 2015, p. 49). Medical devices are equipped with alarms to alert clinicians to signs of progressing instability or equipment malfunction. Alarm fatigue develops when an individual is exposed to an extreme number of alarms resulting in sensory overload (AACN, 2013a). Alarm fatigue is a multifaceted cognitive process that is not voluntarily controlled; it is a human adaptive mechanism activated to manage cognitive burden and attention resources (Gazarian, Carrier, Cohen, Schram, & Shiromani, 2014). Alarm fatigue causes practitioners to become desensitized to alarms. Consequently, alarm response may be delayed or missed altogether. Nurses are the clinicians most directly affected by the cacophony of alarms; they must attend to, interpret, and take action on alarm signals. Nurses react to alarm fatigue by disabling, silencing or ignoring clinical alarms (Cvach, 2012).

In a study conducted by Honan et al. (2015), nurses surveyed expressed a desire to be proactive in responding to alarms and not to become complacent by silencing alarms. Alarm fatigue has resulted in nurses responding that they had silenced alarms without checking the status of the patient. Nurses investigated called for action through collaboration, integrity, and teamwork to solve the problem of alarm fatigue. Surveyed nurses demanded standard competencies for monitor responders. As specified by the Institute of Safe Medication Practices, “awareness of the problem is not an issue—the absence of meaningful action is” (Lukasewicz & Mattox, 2015, p. 46). Education and institutional policies surrounding patient safety in the intensive care unit (ICU) setting is the responsibility of nursing leadership. Nursing leadership

provides education and institutional policies to safeguard patients from a delay of care or worse, a sentinel event.

Background and Significance

One of the first accounts of a sentinel event related to alarms occurred in 1974 (Funk, Clark, Bauld, Ott, & Coss, 2014). Concerns surrounding alarm fatigue were heightened in 2010 when a patient at Boston General Hospital died after a heart monitor alarm was turned off (Gazarian et al., 2014; Honan et al., 2015). The Centers for Medicare and Medicaid Services stated “nurses not recalling hearing low heart rate alarms were indicative of alarm fatigue which contributed to the patient’s death” (Drew et al., 2014, p. 2). The U.S. Food and Drug Administration received reports of 566 patient deaths related to monitoring alarm devices between 2005 and 2008. In 2013, The Joint Commission issued a Sentinel Event Alert on alarm fatigue citing 80 deaths attributed to alarm fatigue between 2009 and 2012 (Bonafide et al., 2014; Cvach, 2012; Funk et al., 2014; Honan et al., 2015). The Joint Commission also reported the death of a 17-year-old high school junior after a routine tonsillectomy; the monitoring equipment was not set correctly, and alarms were muted. When the patient’s condition deteriorated, the staff was not alerted (Sendelbach, Wahl, Anthony, & Shotts, 2015). The Joint Commission released a National Patient Safety Goal (NPSG) on alarm management in 2013. The Joint Commission implemented NPSG in two phases. Phase one began January 1, 2014, requiring hospitals to identify which alarms are essential to manage. Phase two started January 1, 2016, requiring hospitals to develop and implement policies and procedures and educate staff about alarm system management (Funk et al., 2014). The ECRI Institute has named alarm hazards as the number one of the top 10 health technology hazards four years in a row (Cvach, 2012).

The sheer number of clinical alarms experienced within the ICU setting is astounding. As new technology is developed, more alarms will follow. In an observational study of an emergency room, over 371 hours of continuous EKG reported a total of 1,762 alarms. Of those alarms, 11 were adverse events (Gazarian et al., 2014). The remaining alarms were false alarms; this equates to a false alarm rate of 99.4% (Gazarian et al., 2014). Konkani, Oakley, and Bauld (2012) measured a total of 2,176 audible alarms in 928 hours of patient care, and 94% were false alarms. More than 300 physiological monitor alarm signals are estimated to occur each day for each patient (Bonafide et al., 2014). Multiple factors contribute to alarms including redundant alarms, over monitoring, poor signal quality, and inappropriate alarm settings for patient condition (Brantley et al., 2016). Redundant alarms happen when satellite alarm stations are used or multiple devices alarm for the same event. Satellite alarm stations are helpful in monitoring patients from the nurse's station, but it creates alarm sounds in numerous locations. An example of multiple devices that may alarm for a single event would be apnea in a mechanically ventilated patient. The bedside monitor will alarm in addition to the ventilator itself. Over monitoring occurs when patients are monitored without a clinical indication or necessity. The American Heart Association has created guidelines to decrease the number of patients with continuous cardiac monitoring ordered (Lacy, Davis, Tolstrup, & Rendon, 2015). Poor signal quality from EKGs can result from improper skin preparation and electrode management (AACN, 2013a). Finally, the lack of customization of patient alarm limits results in nuisance alarms when patients fall outside of preset limits.

Problem Statement

The ICU setting currently does have a policy in place that follows evidence-based practice recommendations for alarm fatigue reduction. Nursing staff is exhibiting behaviors of

alarm fatigue. The policy is not widely known or utilized by staff. The unit is currently experiencing nuisance alarms resulting from false and inactionable alarms. False alarms are often the result of artifact on EKG tracings. Inactionable alarms such as couplet, bigeminy, and trigeminy are producing an audible alarm due to inappropriate default settings. Staff are not customizing patient alarms specific for each patient condition as written in the alarm management policy. The lack of staff utilization of an evidence-based policy for alarm management puts unnecessary risk on patient safety and increases the likelihood of staff alarm fatigue or of a sentinel event transpiring.

Purpose Statement

The purpose of this project aims to reduce the number of nuisance physiological alarms in the ICU within one month. The project will achieve the outcome of alarm reduction by following evidence-based policies and procedures for alarm management in the ICU. The policies address proper techniques for electrode placement and management to decrease poor signals and nurse-driven alarm limit adjustments according to patient condition. The nursing staff will be educated on the evidence-based practice for alarm management. Following implementation, the number of physiological alarms recorded in the ICU will be compared to documented alarms before policy education.

Project Question & Objectives

The PICOT for the proposed project will be: in the ICU setting, how does a bundled alarm management approach with staff education affect the number of physiological alarms within one month? The objectives of the Doctor of Nursing Practice (DNP) project are:

- By the completion of the DNP project, nursing staff will be able to apply the Clinical Alarms policy to individualize patient alarm limits based on the patient's condition within one month.
- By the completion of the DNP project, nursing staff will be able to describe the correct EKG application procedure and maintenance according to the Application of Telemetry policy within one month.
- By the completion of the DNP project, the ICU will document 50% reduction in nuisance physiological alarms within one month.
- By the completion of the DNP project, nursing staff will document patient alarm limit verification with 80% compliance within one month.

Coverage & Justification

A comprehensive search of the Touro University Nevada (TUN) library databases (ProQuest and CINAHL) and American Association of Critical-care Nurses (AACN) publications was conducted. The AACN database was used to supplement TUN database for the full text of some items. The search was limited to publications between 3/1/2012 and 4/1/2017 to ensure current literature was reviewed. Keywords for the search included alarms, fatigue, nuisance, systems, monitoring, clinical alarms, and physiological alarms. The site for this quality improvement project will be in an adult intensive care unit in Arizona, United States. Articles related to pediatric or neonatal populations and non-critical care units were excluded.

Review Synthesis

Alarm fatigue causes environmental distractions and interferes with a practitioner's ability to perform critical patient care resulting in patient safety issues (West & Abbott, 2014). The literature has demonstrated that significant causation of alarm fatigue is the high number of

false alarms or nuisance alarms. A false alarm is an alert that indicates the presence of a physiological event when no true event has happened (Lukasewicz & Mattox, 2015). Nuisance alarms, or inactionable alarm, are correct alarms that have no clinical significance (Lukasewicz & Mattox, 2015). Together, these alarms can account for as many as 99% of all alarms (Lukasewicz & Mattox, 2015, p. 50). The high number of alarms has prompted much research into alarm fatigue and reduction of alarms. This project aims to reduce false and inactionable physiological alarms in an intensive care unit setting through a quality improvement project supported by current literature.

Current Recommendations

Several themes have emerged for improving alarm fatigue by reducing false and inactionable alarms including the nurse's perspective and call for change, the need for unit-wide policies and protocols to manage alarms, proper care and placement of EKG electrodes, and educational support for nurses.

Funk, Clark, Bauld, Ott, & Coss (2014) found in a national survey that nurses' attitudes and practices surrounding alarm fatigue have not changed since 2005. Nurses continue to rank false alarms as important in contributing to a noisy hospital environment and sentinel events. In Honan et al. (2015), nurses were found to be concerned about the impact of alarm fatigue on nurses and patients. Nurses recognize the importance they can play in decreasing noise pollution; they are calling for accountability and authority for nurses to manage alarms.

The need for well-documented unit-wide policies and procedures for alarm management was well established in the literature (AACN, 2013a; Cvach, 2012; Konkani, Oakley, & Bauld, 2012; Lukasewicz & Mattox, 2015; Mayer, Mauney, Barnes, Addison, Dicus, & Hanlin, 2016). Policies should include default alarms for equipment being used, response protocols, alarms

should be set to actionable limits and levels, and adjustment of alarms for individual patient condition or needs (Cvach, 2012). Individualizing patient alarms was documented as a means to reducing false and inactionable alarms (AACN, 2013a; Benjamin, Bryant, Calloway, Fisher, Gilroy, & Jackson, 2014; Cvach, 2012; Cvach, Rothwell, Cullen, Nayden, Cvach, & Pham, 2015; Drew, Harris, Zegre-Hemsey, Mammone, Schindler, & Salas-Boni, 2014; Konkani et al., 2012; Landsdowne, Strauss, & Scully, 2016; Lukasewicz & Mattox, 2015; Mayer et al., 2016; Sendelbach, Wahl, Anthony, & Shotts, 2015). Adjusted patient alarms for the individual patient condition has shown a 43% reduction in false alarms alone (Konkani et al., 2012). Policies and procedures should include roles and responsibility for alarm management, addressing who can make decisions about alarm parameters, who can change alarm settings, and who is accountable for responding to alarms (Jacques & Howell, 2015; Lukasewicz & Mattox, 2015).

While adjusting alarm limit settings will help combat alarm fatigue, the literature identified proper electrode application and maintenance needed to reduce false alarms (AACN, 2013a; Sendelbach et al., 2015). Skin preparation with soap and water followed by abrading the surface will decrease skin impedance and signal noise (AACN, 2013a). Alcohol solution should never be used in the preparation of the skin as it dries the skin out. Nursing should replace electrodes daily; this action can reduce false alarms by 46% (AACN, 2013a).

Once a well-written policy and protocol is in place, the literature recommends education and training for involved staff members (AACN, 2013a; Brantley, Collins-Brown, Kirkland, Knapp, Pressley, & Higgins, 2016; Gazarian, Carrier, Cohen, Schram, & Shiromani, 2014; Sowan, Gomez, Tarriela, Reed, & Paper, 2016). Education should include the operation of the monitoring systems and alarm settings, customization of alarm limits, review rationale for decreasing false alarms and discuss roles and responsibilities of practitioners in alarm

management (Cvach, 2012). The education should be provided to new staff members and on an on-going basis (AACN, 2013a).

Needs Further Investigation

Despite the overwhelming support for the practices mentioned previously, nursing still requires research on the proper settings for alarm thresholds. The literature agrees that alert parameters should be individualized and tailored to each patient, but the literature does not specify how much variation from default settings are acceptable or how to determine how much to vary from the default settings (Cvach, 2012). The nursing profession also needs research on false alarm suppression algorithms. Lastly, research is required in order to evaluate staff's ability to distinguish device alarms; the best type of audible alarm remains controversial, and medical technology needs to investigate it further.

Review of Study Methods

Authors used a number of research methods in the literature reviewed for this project. Qualitative methods were used to obtain data for the nurse's attitudes and perceptions of alarm management (Honan et al., 2015). Qualitative methods are relevant to this project to discover nurse's attitudes and willingness to buy-in to change current practice. It is evident from the literature that nurses want to see a change in current alarm management and want to be a part of that change. Qualitative methods were used to gain data on nurse's current practice and experience with decision-making in managing alarms (Funk et al., 2014). It is necessary to understand the present practice before one can move forward with changes to improve upon it. Brantley et al. (2016) and Cvach et al. (2015) used randomized controlled trial (RCT) methods to determine the efficacy of decreasing false alarms by altering alarm limits with staff education. Drew et al. (2014) and Landsdowne et al. (2016) used observational study methods to examine

the number and types of false alarms in relation to current monitor settings and limit thresholds. AACN (2013a); Cvach (2012), Konkani et al. (2012), and Lukasewicz & Mattox (2015) provided integrative reviews to explore alarm fatigue and alarm management. Finally, Benjamin et al. (2014), Mayer et al. (2016), Sendelbach et al. (2015) and Sowan et al. (2016) were quality improvement projects that used the above recommendations to improve alarm management and reduce false and inactionable alarms in ICU settings. Alarm safety quality improvement efforts require a change in process and human behavior. Study methods to understand this complex health care issue will need to include both qualitative and quantitative methods to address both human and technological aspects of alarm management.

Significance of Evidence to Profession

Improving patient outcomes by reducing near-misses and sentinel events through evidence-based practice supports the importance of the literature for the nursing profession. The research has demonstrated that alarm fatigue is a real phenomenon within healthcare and has found that false and inactionable alarms are behind the persistent noise in hospitals. Upwards of 99% of alarms are false (West & Abbott, 2014); nurse leaders are being called on by the Joint Commission and ECRI Institute to reduce this hazard. Nuisance alarms pose the risk of causing environmental distractions and interfere with patient care (West & Abbott, 2014). The literature documented that false alarms create a “cry wolf” effect resulting in clinicians’ decreased response to alerts. The quality improvement projects and RCTs documented that bundled approaches to lessen the number of nuisance alarms were successful and could be sustained over time. The reduction of nuisance alarms can decrease stress and fatigue among caregivers. Nurse leaders use nursing frameworks to provide conceptual contexts for quality improvement initiatives (Polit & Beck, 2008).

Historical Development of the Synergy Model

Martha A. Q. Curley, Mairead Hickey, Patricia Hooper, Wanda Johanson, Bonnie Niebuhr, Sarah Sanford, and Gayle Whitman developed the AACN Synergy Model for Patient Care in the 1990s. Initially, the model served as the foundation for the critical-care certification exam. The Synergy Model for Patient Care allowed certification to be grounded on patient/nurse synergy rather than on a series of tasks (Hardin & Kaplow, 2016). Before the model's creation, certification was awarded based on the number of hours worked, number and type of tasks completed, and examination of body systems. Nurse experts believed that a link between nurse competencies for certified practice and patient needs existed; therefore, patient/nurse synergy could be associated with patient outcomes. Since its creation, the Synergy Model has been used to analyze nursing practice, as a conceptual framework for membership at AACN National Teaching Institute, and the creation of Synergy CERPs, the renewal program for critical care certified nurses (Hardin & Kaplow, 2016). The model has gained traction over the years as a useful framework outside of this area. Nurse educators have used the model to develop and implement nursing curricula, orientation programs, preceptorships, and continuing education (Hardin & Kaplow, 2016). Nurses and advanced practice nurses have used the model to determine care for specific patient populations, disease processes, and practice areas. Managers have used the model as a foundation for establishing patient ratios and for productivity (Hardin & Kaplow, 2016).

Major Tenets of Synergy Model

The fundamental principle of the Synergy Model strives for ideal outcomes for patients and families by patient characteristics driving nurse competencies (Hardin & Kaplow, 2016). The patient/nurse partnership is a collaborative relationship where the needs of the patient, clinical unit, or system are paired with the competencies of a nurse, creating synergy. Patient needs and characteristics include physical, social, psychological, and spiritual realms. The Synergy Model defined these features along a continuum from health to vulnerability. The characteristics of patients, clinical units, and systems that the nurse should be concerned about include patient resiliency, vulnerability, stability, complexity, resource availability, participation in care, involvement in decision-making, and predictability. Nurse characteristics reflect the integration of knowledge, skills, experience, and attitudes necessary to meet the needs of patients and families (Hardin & Kaplow, 2016). To obtain excellent results, the nurse must have the skills and level of competency to give appropriate care to the patient. Nurse competencies of concern to patients, clinical units, and systems include clinical judgment, advocacy and moral agency, caring practices, collaboration, systems thinking, response to diversity, clinical inquiry, and facilitation of learning (Hardin & Kaplow, 2016).

The Synergy Model has three levels of results: outcomes of the patient, the nurse, and the healthcare system. Each result is related to the relationship between the patient and nurse. For example, if a patient's illness is complex and unstable, the nurse will need to have advanced clinical judgment and systems thinking to meet the patient's needs. By matching the patient's needs with the nurse's competencies, the impact will be ideal. In the reduction of alarm fatigue, the nurse must possess competencies in equipment use, alarm customization, and electrode application. It is the responsibility of the nurse manager to ensure that his or her nurses are

competent in these areas. Improving patient outcomes will have a positive effect on the healthcare system.

Applicability of the Synergy Model

To survive in a reforming health care system, hospitals and providers must provide the highest quality of care for the lowest cost (Hardin & Kaplow, 2016). Due to health care reform, system outcomes including cost and resource utilization have come under scrutiny to find practices that are maximally effective and efficient. Patient outcomes have evolved into performance ratings that drive hospital reimbursement. Nurse competencies affect the presence or absence of complications by identifying physiological changes and providing necessary treatments (Hardin & Kaplow, 2016). The avoidance of complications equates to higher quality of care and maximal reimbursement by decreasing length of stay in the hospital and readmissions. According to Hardin and Kaplow (2016), the Synergy Model “could serve as a catalyst for nurses to discover the validated needs and characteristics of patients and to reflect upon areas for improvement in personal practice” (p. 9). The Synergy Model applies to many settings in nursing practice because it ensures that nurse proficiencies and patient requirements match. If a mismatch occurs in nursing practice, it can be easily identified and remedied to prevent negative patient consequences and increase the quality of care. The Synergy Model also serves to justify resources for improved patient care. In the previous example, the nurse manager could substantiate 1:1 staffing for the complex and unstable patient to reduce error and complications. If the mismatch is due to lack of knowledge or skills, training could be required to elevate the nurse’s competency.

Application of the Synergy Model to DNP Project

False and inactionable alarms are the result of a mismatch in nursing competencies and patient needs. According to the Synergy Model, positive patient outcomes are the result of nursing competencies and patient needs matching, producing synergy. The issue of alarm fatigue stems from inadequate unit-wide policies and procedures for alarm management, inconsistent electrode application and maintenance, and staff education. The literature has found that creating policies and procedures for alarm management reduces nuisance alarms (AACN, 2013a; Benjamin, Bryant, Calloway, Fisher, Gilroy, & Jackson, 2014; Cvach, 2012; Cvach, Rothwell, Cullen, Nayden, Cvach, & Pham, 2015; Drew, Harris, Zegre-Hemsey, Mammone, Schindler, & Salas-Boni, 2014; Konkani, Oakley, & Bauld, 2012; Landsdowne, Strauss, & Scully, 2016; Lukasewicz & Mattox, 2015; Mayer, Mauney, Barnes, Addison, Dicus, & Hanlin, 2016; Sendelbach, Wahl, Anthony, & Shotts, 2015). Each patient has unique needs that must be examined to create a healing environment (Hardin & Kaplow, 2016). Policy, paired with staff education, will improve nursing competencies required to use critical thinking, collaboration, and systems thinking to adjust threshold limits to meet their individual patient needs and guarantee proper placement and maintenance of electrodes. Education will inform the nursing staff of the importance of reducing alarm fatigue, modifying alarm limits for the patient condition, and proper application and maintenance of electrodes. A significant consequence of nuisance alarms is a delayed or missed response to an actual alarm resulting in a sentinel event. The Synergy Model was used in the DNP project to determine what competencies and resources the nurses possess, what competencies and resources the patients need and develop an educational plan to ensure synergy is generated. The Synergy Model can be used to evaluate the effectiveness of the project. If the nurse's competencies and the patient's needs match, there should be a decrease in

the number of false and inactionable alarms. During the maintenance phase of the project, the Synergy Model can be applied periodically to assess nurses' competencies and evaluate if patient needs are being met.

Description of Project Design

To determine how to address physiological alarms, an interdisciplinary team was assembled. The first step in the process was to collect data the baseline number of alarms. The alarms were analyzed to determine if they were true, false, or inactionable as recommended by AACN (2013b). Physiological alarms were collected from three patient rooms between six o'clock in the morning June 3rd through six o'clock in the morning June 10th. The alarms were individually analyzed to determine if the alarm was a true, false, or inactionable alarm. In examining the alarm data, it was found that inactionable alarms couplet, bigeminy, and trigeminy were producing an audible alarm; these alarms were duplicative of the premature ventricular contraction limit alarm. Other inactionable alarms based on the patient condition were found indicating that nursing staff are not customizing alarm limits for patient needs. An example would be atrial fibrillation alarm signaling for a known patient with atrial fibrillation. False alarms were commonly associated with artifact found on EKG strips. Artifact can occur when skin is not prepped correctly for electrode placement or changed daily (AACN, 2013a). The most common true alarms found were non-sustained ventricular tachycardia and pauses. A total of 294 alarms were collected from the baseline extraction with 222 inactionable alarms and 52 false alarms; this a nuisance alarm rate of 93.2%.

To decrease the number of nuisance physiological alarms, the project will use a bundled approach. The first step will be to eliminate duplicative audible alarms from the default settings. The default settings for couplet, bigeminy, and trigeminy will be changed to "Informational" and

no longer audibly alarm. An “informational” alarm provides a written message on the patient’s monitor to notify nursing of the event. No other changes in default alarm settings are warranted. To determine the effect of changing the default alarm settings, alarm data will be extracted over a period of seven days. The number of false and inactionable alarms (nuisance alarms) will be compared to the baseline data. Following the implementation of default alarm changes, nursing staff will complete a test on their knowledge of electrode placement, maintenance, and documentation and patient alarm customization and documentation per the alarm management policy. Staff exams will be anonymous. The staff will be educated on the proper technique of electrode placement and maintenance, alarm customization setting, and documentation per policy. After staff training, alarm data will be extracted and analyzed for false and inactionable alarms and staff will complete a post-test on their knowledge of alarm management. Staff documentation of electrode daily replacement will be audited before education and after completion of training. The baseline electrode documentation and after intervention electrode documentation will be compared using a McNemar’s test. A chart review will be performed to analyze the compliance of documenting alarm verification; the data will be used to compare compliance with the expected goal of 80%. To analyze the test scores of nurses’ knowledge of alarm management, a Wilcoxon signed rank test will be performed to compare the scores between pre- and post-intervention. To analyze alarm data at baseline, after default settings changed, and after nursing education, a Friedman test will be performed. To encourage compliance with the alarm management policy, nurses will be given badge cards with the major points of the alarm management policy and contact information for questions. In addition, badge cards provide continued education to the nursing staff.

Population of Interest, Setting, Stakeholders, & Recruitment Methods

The population of interest for this project will include the ICU nursing staff. There are approximately 10 ICU nurses employed in this unit. The ICU nursing staff will be included in the project if they are currently employed at the project site as an ICU nurse. There will not be any exclusion criteria. The sample for the project will be a convenience sample from the ICU at the project site. The quality improvement project will be conducted in a six bed, adult medical-surgical ICU within a rural acute care hospital that is staffed for 49 beds. The primary populations of patients are geriatric patients with acute coronary syndrome, respiratory failure, sepsis, and congestive heart failure. The physical unit design is a nurses' station with rooms making an L shape around the nurses' station. A central monitor is positioned at the nurses' station without a designated monitor watcher. Each nurse is responsible for monitoring his or her patients. Permission from Director of Nursing at the project site has been granted to carry out the quality improvement project. Stakeholders in the project include the ICU staff nurses, Inpatient Nursing Manager, Director of Nursing, Chief Nursing Officer (CNO), and Chief Executive Officer (CEO). The Inpatient Nursing Manager and Director of Nursing are responsible for daily leadership in the ICU; rapport has been established with these individuals, and a collaborative team has been created. The Director of Nursing will be reporting updates and progress to the CNO and CEO. The interdisciplinary team includes ICU staff nursing, Inpatient Manager, Director of Nursing, and Monitor Superuser. The education and training on the alarm management policy and procedures will be mandatory for ICU nurses. Nurses will be recruited for the training as a condition of employment.

Tools/Instrumentation

In this quality improvement project, four sets of data will need to be collected and analyzed: number and type alarms, daily electrode changes, alarm limit documentation, and nursing staff scores on the alarm management test.

Alarm Data Collection

Alarm data will be extracted and analyzed according to AACN (2013b) recommendations. The monitoring system used within the ICU is the GE Dash 5000™ patient monitor at the bedside with accompanying central monitor system at the nurses' station. Alarm data will be extracted over a seven-day period before the intervention, after default limits have been changed, and after staff education is complete. A convenience sample will be used for the alarm data extraction. Alarm data will be extracted from three patient rooms each day over a seven-day period to capture patient alarm activity of the nurses from the day and night shifts. The convenience sample will create a total of 21 samples. Once the alarm data has been obtained, each alarm will be individually reviewed to determine if the alarm is a true, false, or inactionable alarm. There will not be any patient identifiers or other health information collected during the extraction process. Each alarm audit will be assigned a number for coding purposes. The alarm extraction tool is provided in Appendix A.

Electrode Daily Replacement

To evaluate the practice of daily electrode replacement and documentation, a chart audit will be performed on random patients at two separate periods: before implementation and post-implementation. The sample will include 30 patients: 15 patient charts pre-implementation and 15 patient charts post-implementation. The chart review will examine if the nursing staff has documented daily electrode replacement only. Patient identifiers or other health information will

not be collected during the chart review. Each chart audit will be assigned a number for coding purposes. The electrode audit tool is provided in Appendix B.

Alarm Verification

Per the alarm management policy, it is each nurse's responsibility to verify alarm parameters are set and appropriate for the patient's condition. A chart audit will be performed on random patients post implementation of the quality improvement project to evaluate the documentation of alarm verification. The unit does not currently have a practice for documenting that nurse has verified alarms parameters. The sample will include 15 patient chart audits and will consist of both the day and night shift. The chart audit will review if the nursing staff has documented verification that alarm parameters are patient-specific on the telemetry strip printed from the central monitor every eight hours. Patient identifiers or other health information will not be collected during the chart review. Each audit will be assigned a number for coding purposes. The alarm verification documentation audit tool is located in Appendix C.

Alarm Management Test

The purpose of the education is to improve ICU nurses' knowledge of alarm management. The training will provide instruction on the proper technique for electrode application. It will also offer training on alarm customization per patient condition and equipment use.

Learning outcomes.

Upon completion of the training, you will be able to:

1. Describe proper technique for applying electrodes
2. Perform patient documentation of electrode replacements and alarm limit review

3. Analyze various alarms to determine cause (artifact, inactionable, etc.) and demonstrate how to customize alarm limits on GE Dash 5000™ patient monitors

Test items.

The test will include ten questions including multiple choice and true-false items.

According to Billings and Halstead (2012), a criterion-referenced test is used to measure mastery of subject matter. A criterion-referenced test uses specific learning outcomes to construct and interpret results. A test blueprint was in the construction of the test. The test questions are located in Appendix D.

Table 1

Test Blueprint

Content	Cognitive Level				Total
	Knowledge	Comprehension	Application	Analysis	
Electrode application	2	1			3
Alarm analysis & customization	1		1	3	5
Patient Documentation	1		1		2
Total	4	1	2	3	10

Test analysis.

Prior to the first use, the test's content validity was determined by calculating the content validity index (CVI). Three experts evaluated individual items on the test as well as the overall test. Both the item-level CVI (I-CVI) and scale-level CVI (S-CVI) were calculated. All items on the exam had an I-CVI of 1.0, and the S-CVI was 1.0. An acceptable I-CVI and S-CVI are 0.8 and 0.9 respectively (Polit & Beck, 2008). The CVI tool for this test can be found in Appendix E. The test will be analyzed by calculating the reliability coefficient using Kuder-

Richardson Formula 20 (KR-20). A reliability coefficient of 0.7 to 0.8 is acceptable for testing (Billings & Halstead, 2012).

Data Collection Procedures

Once recruitment has been completed, data collection will begin for the number of alarms, electrode daily replacement charting, and alarm management test scores. As recommended by AACN (2013b), alarms have been extracted and categorized over a seven-day period between June 3rd and June 10th 2017 to determine current alarm concerns. Alarm extraction and categorization over a seven-day period will be done after default settings have been modified. Alarm extraction and categorization will allow for comparison between baseline data and after defaults have been changed. Staff education will be provided with electrode application and replacement and alarm parameter customization. The staff training will consist of a poster presentation with a hands-on demonstration of alarm customization and handouts. The education session will be at the change of shift in the evening. The educational handouts can be found in Appendix F. A final alarm extraction and categorization over a seven-day period will be completed after the education has been finalized. A Friedman's test will be performed to analyze the alarm data at baseline, after modifying the defaults, and after staff education. During the alarm data extraction, no patient identifiers will be obtained. Each alarm extraction will be coded with an assigned number. Electrode documentation chart audits will be performed during the baseline alarm extraction and final alarm extraction; no patient identifiers will be obtained during the chart audit. A McNemar's test will be conducted to compare the baseline documentation with the post-education documentation. The alarm verification chart audits will be performed during the final alarm extraction. Because there are not currently any practices in

place for documenting alarm verification, the proportion of correctly documented alarm verification will be examined with an 80% compliance goal.

The test will be administered on paper. A separate answer sheet (Appendix G) will be used to develop a computer-generated item analysis report; it will not contain any identifying information about the test taker. The original tests with employee name will be stored securely in the employee education file at the site. A Wilcoxon signed rank test will be performed to compare the baseline scores on alarm management test with the post-education test scores.

Project Timeline

School IRB approval will be completed by October 20th. An alarm management team has been assembled during the planning phase and includes the practice mentor, ICU Manager, Director of Nursing, and monitor superuser. The project implementation phase will begin on November 1st, 2017, with the adjustment in default alarm parameters to eliminate the duplicative alarms: couplet, bigeminy, and trigeminy. These alarms will be adjusted from low priority to informational on the GE Dash 5000 monitors. The monitor superuser will assist with the alarm adjustments. Beginning November 5th at six o'clock in the morning, alarm data will be extracted and analyzed over a seven-day period to determine if alarms are true, false, or inactionable. During this time, random chart audits will be performed on 15 patient charts examining documentation for daily electrode changes and a pre-education test will be given to ICU nursing staff. All ICU nursing staff will be required to participate in the pre- and post-education test. Recruitment will be done on a condition of employment. Alarm management training will begin on November 12th. The training will be performed on the unit at the change of shift in the evening. The education will include a poster presentation, handouts, badge care reminders, and hands-on demonstration of customizing alarm parameters. The education will be held over a

one-week period to ensure every nurse has the opportunity to engage in the training. Following the training, each nurse will be required to take a post-education test. Alarm extraction and chart audits on daily electrode replacement, and alarm verification will be performed between November 18th and 25th. Once all data has been collected, the data will be analyzed in collaboration with the practice mentor beginning November 26th and completed by December 5th. The action plan and project timeline can be found in Appendix H and Appendix I respectively.

Human Subjects Protection

The practice site will not require separate IRB approval to carry out the quality improvement project. To protect ethical project implementation and human subjects, measures will be put in place to prevent confidentiality and privacy breaches. To safeguard patient healthcare information, no patient identifiers or medical information will be taken during alarm extractions or chart audits. Each extraction and chart review will be assigned a coding number to maintain privacy. The data will be shared only with the alarm management team after coding has been completed to maintain confidentiality. The practice will house original exams with nurses' names in each nurse's education file. A separate answer sheet will be used to transcribe answers for data analysis. The transcribed answer sheet will not contain any personal information about the test-taker. For confidentiality purposes, the only individuals with access to the exams, once the transfer of the answers to a separate answer sheet has been completed, will be the nurse themselves and their direct supervisor. The benefits of participating in this quality improvement project include increasing knowledge of alarm management, the promotion of patient safety, and creating a healthier work environment. There are no risks to participating in the quality improvement project. Participants will receive his or her hourly wage for time spent

in the educational session and completion of the pre- and post-test; there will be no other form of compensation for participating.

Plan for Analysis

This quality improvement project will use a bundled approach to reduce nuisance alarms in the ICU. The goal of the project is to decrease the number of nuisance alarms within three months. The analyses of each statistical test will be achieved using IBM SPSS Statistics version 24.

Nuisance Alarms

To evaluate the change in nuisance alarms across the three time periods (pre-intervention, post-default adjustments, and post-education), a Friedman Test will be used to measure the same sample of cases at three or more points in time, under three different conditions (Pallant, 2013). For this analysis, the alpha value will be 0.05. If statistical significance is found from the Friedman Test, a post-hoc test will be completed. In this case, post-hoc testing would involve individual Wilcoxon Signed Rank Tests. Because the data will include less than 30 samples, a non-parametric test was selected over the parametric equivalent. The assumptions for using non-parametric techniques have been met by using random samples, and the independent observations do not apply to repeated measures techniques.

Daily Electrode Replacement

To evaluate the change in the documentation of daily electrode replacement, a McNemar's Test will be performed. A McNemar's Test uses two categorical variables measuring the same characteristic collected at different time points (Pallant, 2013). The categorical variables will be either "yes" or "no" for correct documentation of electrode replacement daily. The data will be collected prior to and after the educational session on

electrode application and documentation. Each sample will include 15 chart audits. For this analysis, the alpha level will be 0.05. A p-value of less than 0.05 would suggest that there was a significant change in the proportion of daily electrode replacements documented. The assumptions for using non-parametric techniques have been met by using random samples, and the independent observations do not apply to repeated measures techniques.

Alarm Verification

To evaluate whether nursing staff are documenting alarm verification equivalent to the set goal of 80%, data will be collected prior to and after the educational session on alarm customization and documentation. Each sample will include 15 chart audits. Nursing staff did not document alarm parameter verification prior to this quality and improvement project. There is no baseline data to compare the post-education results with. The proportion of documented alarm verification should be 80% to meet the project's goal.

Nursing Staff Education

A Wilcoxon Signed Rank test will be used to compare the scores on the alarm management test from pre-education to post-education. The Wilcoxon Signed Rank test is designed for repeated measures; it is the non-parametric equivalent to the repeated measures t-test (Pallant, 2013). The non-parametric test was selected to avoid violating the normal distribution assumption for parametric tests. The alpha level will be 0.05 for this analysis. A p-value of less than 0.05 and an increase in the median scores would suggest a significant increase in nurses' knowledge of alarm management. The assumptions for using non-parametric techniques have been met by using random samples, and the independent observations do not apply to repeated measures techniques.

Significance for Nursing

The proper management of patient alarms will improve both patient safety and create a healthier environment. The quality improvement project will enhance patient safety by preventing the development of alarm fatigue through reduction of false and inactionable alarms. The development of alarm fatigue may result in caregivers disabling, silencing, or ignoring the alarm warnings (Cvach, 2012). Alarm fatigue has contributed to several documented deaths; in these cases, patient's alarms were muted or turned off resulting in a delay in response to patient decompensation (Sendelbach & Funk, 2013). The reaction rate of nurses is matched to the perceived true alarm rate; if the perceived true alarm rate is 10%, the nurse response rate will be about 10% (Cvach, 2012). Given the current status of the unit's nuisance alarm rate of 93.2%, the nurses' alarm response rate could be less than 10%. The high nuisance alarm on this unit creates the dangerous likelihood of near-miss or missed critical events. This quality improvement project aims to increase the validity of alarms and provides an early warning of a potential crisis. Improving the validity of alarms on the unit will also have a positive impact on workload and performance. Each time an alarm sounds, the nurse must stop their current task and assess the patient. When alarms are reliable and valid, the nurse can prioritize tasks correctly and limit interruptions during critical tasks such as maintaining a sterile field. The reduction of nuisance alarms will limit disruptions and allow nurses to focus on critical duties.

A quieter environment is a healthier environment for staff, patients, and visitors. Alarms generate noise pollution that may present occupational hazards and hinder patient recovery (Cvach, 2012). Noise can affect patient's sleep in the hospital affecting the central nervous system, respiratory system, cardiovascular system, immune system, and metabolism (Boesen, Andersen, Bendtsen, & Jennum, 2016). The World Health Organization (WHO) recommends

noise levels to be 35 decibels during day hours and 30 decibels during night-time; most hospitals exceed these recommendations (Cvach, 2012). Over half of medical equipment have an alarm sound that exceeds 70 decibels (Cvach, 2012). Medical equipment often does not offer the ability to reduce or modify the decibel settings. Excessive noise adds to staff stress symptoms including exhaustion, concentration problems, and tension headaches (Cvach, 2012). The reduction in the number of alarms can assist with reducing overall noise within the intensive care unit.

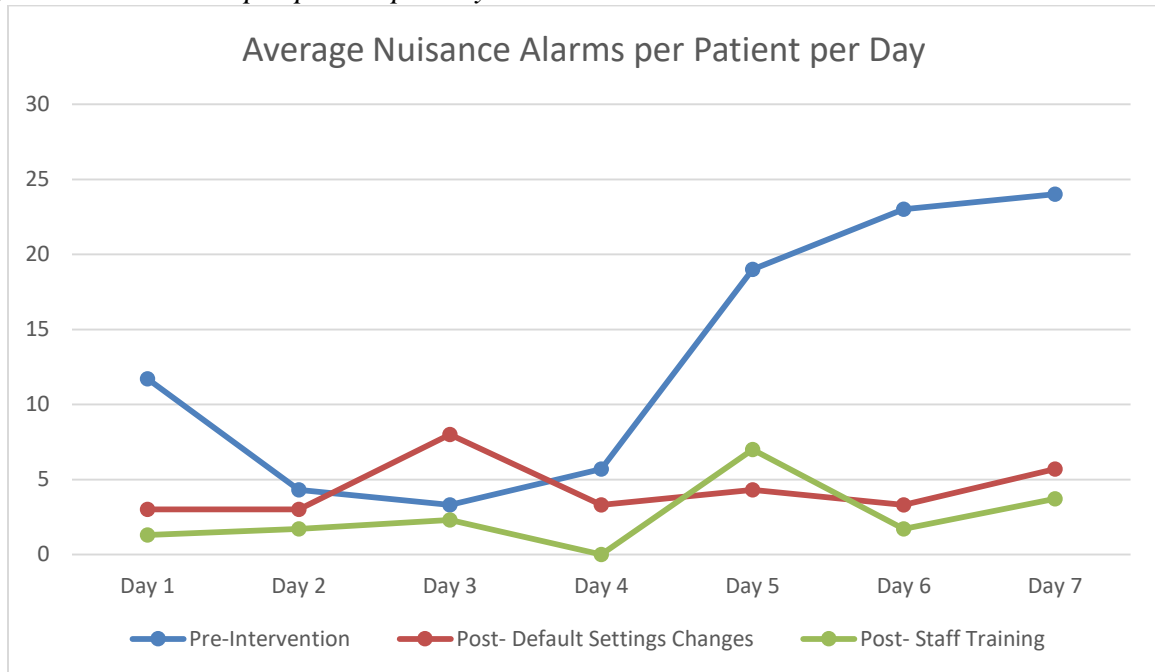
The financial implications of the quality improvement project include the cost of care associated with hospital-related complications, nurse workload reduction, and cost of implementation. The evidence has shown that alarm fatigue directly affects nurses alarm management behavior by disabling, silencing, or ignoring alarms. Practices associated with alarm fatigue have resulted in patient injury and death (Sendelbach & Funk, 2013). Alarm mismanagement can lead to near-misses or missed events in the ICU. Complications can be costly to the organization including longer length of stay in the ICU and additional treatments. Excluding litigation costs, each adverse event costs about \$8,750 according to the Institute of Medicine (Physician-Patient Alliance for Health & Safety, 2013). With each false alarm, the nurse must take time away from their current task to assess the patient. Distraction can lead to medical errors and adverse events. A high nuisance alarm rate produces inefficiency and increased workload for the nurse. The quality improvement project uses existing infrastructure, and the cost of implementation is small. Costs associated with implementation will include staff time to collect and analyze data, complete educational in-service, and continued evaluation of alarm management within the organization.

Analysis of Results

In this quality improvement project, a bundled approach including deletion of duplicative alarms from default settings, customization of alarms for the patient condition, and daily electrode changes with correct skin preparation was associated with an 81% reduction in nuisance alarms in the ICU. The baseline data revealed a mean of 13 nuisance alarms per day per monitored bed. With the deletion of duplicative alarms, the mean number of nuisance alarms was reduced to four nuisance alarms per day per monitored bed (Figure 1). After the staff was educated on alarm customization for patient condition and daily electrode changes with correct skin preparation, the mean number of nuisance alarms was reduced to three nuisance alarms per day per patient. To determine if there was a change in the number of nuisance alarms across the three time periods (pre-intervention, post-default setting changes, and post- staff training), a Friedman Test was performed using IBM SPSS Statistics, version 24. The results of the Friedman Test indicated that there was a statistically significant difference in nuisance alarms across three-time points (pre-intervention, post-default settings changes, post- staff training $\chi^2(2, n= 21) = 15.61, p < 0.001$). Inspection of the median values showed a decrease in nuisance alarms from pre-intervention (Md=6) to post-default settings changes (Md=3) and a further decrease post- staff training (Md=1). A post-hoc analysis was conducted to compare the pre-intervention nuisance alarms to post-staff training nuisance alarms. A Wilcoxon Signed Rank Test revealed a statistically significant reduction in nuisance alarms following staff training, $z = -3.04, p = 0.002$, with a medium effect size ($r = 0.47$). The median number of nuisance alarms decreased from pre-intervention (Md= 6) to post- staff training (Md= 1). The quality improvement project achieved its objective to document a 50% reduction in nuisance physiological alarms in the ICU within one month.

Figure 1

Average nuisance alarms per patient per day



Alarm Management Training

A nursing staff training session on alarm customization, daily electrode changes with correct skin preparation, and GE Carescape Central Station use was conducted. Nursing staff demographics and experience can be found in Table 1. To determine if there was a change in knowledge of alarm management, the scores on the Alarm Management Test from pre-education to post-education on alarm management were compared. A Wilcoxon Signed Rank test revealed a statistically significant increase in alarm management knowledge following participation in the training session, $z = -2.68$, $p = 0.007$, with a large effect size ($r = 0.57$). The median score on the Alarm Management Test increased from pre-training ($Md = 5$) to post-training ($Md = 10$).

The Kuder-Richardson Formula 20 (KR-20) was used to measure the reliability of the Alarm Management Test. The Alarm Management Test has good internal consistency, with a reliability coefficient of 0.59. According to Ignatavicius (2017), several factors can affect the

reliability coefficient of a test: length of the test (less than 40 items) and the size of the test group. The length of the Alarm Management Test and small sample size resulted in a lower reliability coefficient than the expected 0.7 to 0.8.

Table 1

Nursing staff demographics and experience

Characteristic	Number	Percentage
Age		
≤24	0	0
25-34	2	16.7
35-44	1	8.3
45-54	5	41.7
55-64	4	33.3
≥65	0	0
Gender		
Male	1	8.3
Female	11	91.7
Education		
Diploma/ADN	8	66.7
BSN	3	25
MSN	1	8.3
Doctorate	0	0
ICU Experience in Years		
<3	1	8.3
3-<5	3	25
5-<10	2	16.7
≥10	6	50
Shift		
Days	6	50
Nights	5	41.7
Varies	1	8.3
Hours/Week		
≤12	0	0
13-24	1	8.3
25-39	9	75
≥40	2	16.7

Daily Electrode Changes

A chart audit was performed on 15 charts to determine if there was a change in the proportion of correctly documented electrode daily changes prior to, and following the

intervention. A McNemar's Test revealed a significant difference ($p=0.004$) in the proportion of correctly documented daily electrode changes following staff training (66.7%) when compared to the proportion of correctly charted daily electrode changes prior to staff training (6.7%). The quality improvement project objective of nursing staff will be able to describe the correct EKG application procedure and maintenance according to the Application of Telemetry policy within one month was met as evidenced by increased knowledge and correct documentation.

Alarm Verification

An essential aspect of reducing nuisance alarms is to customize and verify patient alarms are set to their specific condition. A chart audit was performed on 15 charts to determine if the staff training resulted in documentation of patient alarm limit verification. The chart audit revealed that staff correctly documented patient alarm limit verification 87% of the time. The quality improvement project objective of nursing staff will document patient alarm limit verification with 80% compliance within one month was met.

Discussion

In this quality improvement project, the team was able to demonstrate an 81% reduction in the number of physiological nuisance alarms in the ICU. This decrease is consistent with other published quality improvement efforts (AACN, 2013; Benjamin et al., 2014; Cvach, 2012; Cvach et al., 2015; Drew et al., 2014; Konkani et al., 2012; Landsdowne et al., 2016; Lukasewicz & Mattox, 2015; Mayer et al., 2016; Sendelbach et al., 2015). The bundled approach to managing physiological alarms in the ICU has met the objectives of the quality improvement project. Sendelbach et al. (2015) suggest that if an individual experiences a system that is 10% reliable, then the individual will respond 10% of the time. The ICU had a nuisance alarm rate of

93.2% equating to a response rate of less than 7%. By reducing the number of nuisance alarms, the reliability of the system has increased to 28%.

The most significant change in the number of alarms occurred after the default settings were changed and the staff was educated on alarm management. The mean number of alarms before the intervention was 13 nuisance alarms per patient per day and 3 nuisance alarms per patient per day after the default settings were changed and the staff was educated on alarm management. The results indicate that removing inactionable alarms from the default settings alone were not sufficient to reduce nuisance alarms. The 15 to 20-minute alarm management education provided each shift with the elimination of inactionable alarms was able to demonstrate a significant reduction in nuisance alarms. This indicates that alarm fatigue cannot be corrected by only manipulating settings, but must also include modifying human behavior. The practice site does not have a formal nurse educator position to provide training and remediation for staff nurses in implementing policies and procedures. The training and increased knowledge of staff nurses likely contributed to the decrease in nuisance alarms.

Significance for Nursing

The significance of the findings to the profession of nursing continues to support the bundled approach to decrease nuisance alarms. The reduction of nuisance alarms will have an impact on not only patient safety and outcomes but caregiver stress and fatigue. The quality improvement project followed the tenets of the Synergy Model by increasing nurse competency in alarm management resulting in a positive change in clinical practice. The reduction of alarms will create a safer and more healing environment for patients and their families. It is difficult to quantify the savings on alarm reduction because it is hard to measure a life saved because a critical alarm was not missed or prevention of patient delirium because of a decrease in

environmental noise (Mayer et al., 2016). The savings can be measured by monitoring the reduction in sentinel events and delays in care related to monitor alarms.

The quality improvement project further supported the need for continual nurse training and development. The outcomes of this project have led to a system change resulting in the creation of a full-time nurse educator position at the practice site. Nursing leadership was able to demonstrate the positive effects of nurse education on patient safety and outcomes to hospital administrators. The practice site already had an evidence-based policy for alarm management, but without formal training of the staff, the nurses did not have the tools needed to be successful. The data will be used to continue to implement the bundled approach to managing alarms in the ICU. Sustainability will be determined by examining alarm data in the future. The literature recommends regular re-education for nurses on alarm management to maintain the results. The team will provide ongoing education for the nurses within the ICU and monitor alarm data in an effort to sustain the positive effects of this quality improvement project.

The data of this project will be used to create practice change in other departments of the practice site including the emergency department, post-anesthesia care unit, special procedures department, and telemetry unit. These units will replicate the steps taken in the ICU to reduce nuisance alarms within their departments. The quality improvement project in the ICU will result in a positive change for the entire practice site. The data from the alarm management exam revealed that having an evidence-based policy is not sufficient to foster evidence-based practice. This data prompted the practice site to examine other knowledge and training deficiencies among nurses that may be present. The quality improvement project has resulted in the practice site adopting a culture that emphasizes the importance of customizing alarm parameters for each patient's needs and changing electrodes daily with correct skin preparation.

This quality improvement project contributes to nursing practice by revealing that alarm fatigue is an unconscious behavior developed by desensitization over time. Alarm fatigue is a complex issue involving both biotechnology and human behavior. When biotechnology is not used correctly or incorrectly set, it is less reliable resulting in nurses not using alarm devices (Cho et al., 2016). Frequent false alarms produce a cry wolf effect that may cause nurses to deem significant alarms as false and thus respond inappropriately. The fact is nurses do not respond to alarms because they know most alarms are not reliable (Funk et al., 2014). The project examined the problem from a scientific perspective allowing nurses to use evidence-based interventions to improve the problem. Evidence-based interventions encompassed both biotechnological and nursing practice behaviors to make patient monitors more reliable.

Limitations

This project had several potential limitations. First, this is a quality improvement project, and cannot determine a cause and effect relationship; the project cannot say that any one intervention produced more or less of a decrease in the number of nuisance alarms. Additionally, the results are not generalizable. Second, the project took place over a three- week period of time. Data were collected only pre-intervention and immediately after each intervention. The project did not investigate the long-term effect or the sustainability of the project. Third, due to the size of the ICU, the sample of nurses and alarm data were small. Therefore, non-parametric tests were needed to analyze the data in this project. Finally, this QI project was limited to alarms from the bedside monitor and did not include other frequently used devices that alarm in the ICU, such as ventilators or intravenous infusion pumps.

Further Dissemination

The *Critical Care Nurse* is a peer-reviewed journal for high acuity, progressive, and critical care nursing. Alarm management and prevention is a top ten area of interest for the American Association of Critical-care Nurses. This QI project will be submitted for publication in this journal to disseminate the findings. The American Association of Critical-care Nurses has a community of more than 100,000 nurse members (AACN, 2017). Each member receives access to the *Critical Care Nurse* journal as part of their membership. This platform of dissemination will guarantee critical care nurses have access to the findings of this project. If the project is not accepted for publication, the project will be submitted for poster presentation at the National Teaching Institute and Critical Care Exposition (NTI). The NTI conference has historically reached 8,000 critical care nurses in attendance. Both of these methods of dissemination will have the potential to reach the target population of critical care nurses.

Moran (2016) recommends using an executive summary to present the project outcomes within the organization that the project was implemented. An executive summary will be provided to the practice site and will be disseminated to the Inpatient Nursing Manager, Director of Nursing, Chief Nursing Officer, and the nursing staff of the ICU. The executive summary will serve to disseminate the outcomes and recommendations of the project to the administration and nursing staff at the practice site.

Project Sustainability

To maintain project sustainability, Cvach (2012) recommends initial and ongoing training in alarm-based medical devices that staff are expected to operate. Clinical competency that reflects institutional policy validates ICU staff nurses' skill and competency with physiological monitoring devices. Honan et al. (2015) suggest requiring annual competency training related to

alarms. Alarm management training will be included in the yearly skill competency evaluation at the practice site. In addition, training will be offered as needed to staff to support the continued success of the project. Data will need to be extracted and analyzed on a routine basis to determine if additional training is warranted. The unit will be held accountable for sustaining a zero-tolerance for nuisance alarms and troubleshooting these alarms as they occur. Alarm management policy and procedure training have been incorporated into the onboarding orientation to the ICU. It is the responsibility of the direct supervisor and nurse preceptor to train the newly hired nurse in alarm management. Lastly, the alarm management team will review the current literature regarding alarm management and revise the current policy and procedure as needed to ensure the best practices are being executed.

Conclusion

Alarm fatigue is an unconscious behavior acquired by desensitization over time. Approximately 99% of alarms are false alarms; this leads to monitoring devices being unreliable. This QI project demonstrated that implementation of evidence-based interventions could reduce the number of physiological nuisance alarms in a medical ICU. By addressing both biotechnological and human behavior issues concerning alarm management, the project was able to decrease nuisance alarm signals by 81%. The goal of reducing the number of nuisance physiological alarms in the ICU within one month was achieved.

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Appendix A

Alarm Extraction

Date:				
Audit #	True Alarms	False Alarms	Inactionable Alarms	Total Alarms

Appendix B

Electrode Audit Tool

Date:	
Audit #	Electrodes changed (Y/N)?
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Appendix C

Alarm Verification Audit Tool

Date:	
Audit #	Alarm verification documented (Y/N)?
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	

Appendix D

Alarm Management Test

1. The nurse understands that the alarm priority has been changed on the selected patient when the alarm priority text is blue.
 - a) True
 - b) False

Answer: True Knowledge- Alarm customization

Rationale: The default color for alarm priority text is black. When the alarm priority has been changed from the default setting, the priority text changes to blue.

2. A patient is admitted to ICU with atrial fibrillation with rapid ventricular response with a heart rate of 150 bpm. The patient has a known history of atrial fibrillation. The nurse has orders to begin a Cardizem gtt and titrate for a heart rate less than 100 bpm. The nurse correctly customizes the patient's default alarm limits by (Select ALL that apply):
 - a) Setting the atrial fibrillation alarm priority to informational
 - b) Setting the HR limit alarm priority to informational
 - c) Setting the HR high limit to 165
 - d) Contacts the physician for alarm parameter settings

Answer: A & C Analysis- Alarm Customization

Rationale: The patient has a known diagnosis and history of atrial fibrillation. There would not be an actionable reason to have an audible alarm for atrial fibrillation. The alarm setting for atrial fibrillation should be turned to informational to provide a visual message of atrial fibrillation only. The patient has a known HR of 150 bpm with orders to treat. Per the Green Valley Hospital policy, the nurse may set alarm parameters 5-10% of expected. The physician does not need to be contacted for alarm parameter settings per the Alarm Management policy.

3. To ensure the best EKG reading, electrodes should be replaced every ____ per hospital policy.
- a) 48 hours
 - b) 96 hours
 - c) 24 hours
 - d) Only when they fall off

Answer: C Knowledge- Electrode application

Rationale: Daily electrode replacement has been shown to decrease the number of false alarms. Electrodes should be replaced if they fall off, but this is not the only time electrodes should be replaced.

4. A patient with a history of COPD who wears oxygen at home. The physician has provided an order to titrate oxygen to maintain an oxygen saturation greater than or equal to 87%. The nurse correctly customizes the patient's alarm settings by setting the SpO₂ low limit to 87%.
- a) True
 - b) False

Answer: A Application- Alarm Customization

Rationale: An alarm above 87% would not require any action by the nurse per the physician's order. The alarm should be set to an actionable limit.

5. A patient on continuous cardiac monitoring has an electrode fall off. The nurse understands that the best action is to:
- a) Replace only the electrode that has fallen off
 - b) Replace all the electrodes
 - c) Nothing as long as the other four leads are reading appropriately
 - d) Re-apply the electrode that has fallen off

Answer: B Comprehension- Electrode application

Rationale: The nurse should replace all the electrodes. One electrode has already fallen off indicating that the conduction in the remaining electrodes may be limited. To ensure reduction of skin impedance and signal noise, the nurse should replace all the electrodes.

6. A nurse has just replaced the electrodes on his or her patient. The nurse knows that proper documentation of electrode replacement should be entered in Cerner in which location:
- a) Cardiac monitor activity in the Adult ICU Systems Assessments tab
 - b) Electrodes changed in the Adult ICU Skin- ADL- Nutrition tab
 - c) Progress note
 - d) EKG comment in the Adult ICU Systems Assessments tab

Answer: B Application- Documentation

Rationale: The correct place to document electrode placement is in the Adult ICU Skin- ADL- Nutrition tab. In the same section, proper skin preparation should be recorded including the use of soap and water.

7. A patient with tremors is on continuous cardiac monitoring and pulse oximetry. The nurse notes that V-tach and low SpO2 alarms are signaling. The nurse promptly checks on the patient and determines that the tremors are interfering with the readings causing false alarms. The nurse corrects the problem by (Select ALL that apply):
- a) Setting the V-tach alarm priority to informational
 - b) Stabilize the electrode with a lead wire stress loop near the electrode
 - c) Increase the SpO2 alarm delay
 - d) Setting the SpO2 alarm priority to informational

Answer: B & C Analysis- Alarm Customization

Rationale: Setting the V-tach and SpO2 alarm priority to informational would stop all future audible alarms putting the patient at risk for a near-miss or missed critical event. Using a lead wire stress loop near the electrode prevents tugging on the electrode and decreases EKG artifact. Increasing the SpO2 alarm delay will allow the monitor additional time to sense the patient's oxygen before alarming.

8. A patient is admitted with new-onset atrial fibrillation with a heart rate of 140. The nurse adjusts the alarm settings for this patient by changing the atrial fibrillation alarm priority to informational and increases the heart rate limit to 154. The patient undergoes a cardioversion and is now in normal sinus rhythm. The nurse correctly customizes the patient's alarm limits by (Select ALL that apply):
- a) Re-setting the atrial fibrillation alarm priority back to the default setting
 - b) Maintaining atrial fibrillation alarm priority at informational as the patient may go back into atrial fibrillation
 - c) Re-setting the heart rate alarm limit back to the default setting
 - d) Maintaining the heart rate limit because the patient may go back into atrial fibrillation with RVR

Answer: A & C

Analysis- Alarm customization

Rationale: The nurse should return both the atrial fibrillation priority alarm and heart rate limit alarm back to the default settings. Maintaining either setting would prevent future alarms if the patient becomes tachycardic or goes back into atrial fibrillation putting the patient at risk for a near-miss or missed critical event.

9. The nurse is required to verify and reset, if necessary, the alarm parameters at the beginning of each shift, when the nurse returns from breaks, when the patient is turned or moved, or after patients are transferred. The nurse will document verification of alarm parameters on the EKG strip.
- a) True
 - b) False

Answer: A

Knowledge- Documentation

Rationale: Per hospital policy, the nurse must verify and reset, if necessary, the alarm parameters at the beginning of each shift, when the nurse returns from breaks, when the patient is turned or moved, or after patients are transferred. It is the nurse's responsibility to ensure alarms are appropriate for the patient.

10. Proper skin preparation for electrode application includes all of the following except:

- a) Wash the skin with soap and water
- b) Wiping the skin with a washcloth
- c) Date and time electrode
- d) Clean skin with alcohol to remove excess oil

Answer: D Knowledge- Electrode application

Rationale: Wiping the skin with alcohol will dry out the skin and decreases conductivity. A & B reduce skin impedance and signal noise, reducing artifact. Date and time on the electrode will increase compliance with daily electrode replacements.

Appendix E

Experts Rating Form

Rating instructions: For each item, please indicate the following:

1. How relevant each item is to the overall construct of alarm management test by placing a number in the box to the right of each item.
 - 1 = Not relevant at all
 - 2 = Slightly relevant
 - 3 = Moderately relevant
 - 4 = Highly relevant

Your honest feedback is appreciated and will be used to enhance the quality of this questionnaire.

Item	Relevance Rating
1. The nurse understands that the alarm priority has been changed on the selected patient when the alarm priority text is blue. <ol style="list-style-type: none"> a. True b. False 	
2. A patient is admitted to ICU with atrial fibrillation with rapid ventricular response with a heart rate of 150 bpm. The patient has a known history of atrial fibrillation. The nurse has orders to begin a Cardizem gtt and titrate for a heart rate less than 100 bpm. The nurse correctly customizes the patient's default alarm limits by (Select ALL that apply): <ol style="list-style-type: none"> a. Setting the atrial fibrillation alarm priority to informational b. Setting the HR limit alarm priority to informational c. Setting the HR high limit to 165 d. Contacts the physician for alarm parameter settings 	
3. To ensure the best EKG reading, electrodes should be replaced every ____ per hospital policy. <ol style="list-style-type: none"> a. 48 hours b. 96 hours c. 24 hours d. Only when they fall off 	

<p>4. A patient with a history of COPD who wears oxygen at home is currently admitted to the ICU. The physician has provided an order to titrate oxygen to maintain an oxygen saturation greater than or equal to 87%. The nurse correctly customizes the patient's alarm settings by setting the SpO2 low limit to 87%.</p> <ol style="list-style-type: none"> True False 	
<p>5. A patient on continuous cardiac monitoring has an electrode fall off. The nurse understands that the best action is to:</p> <ol style="list-style-type: none"> Replace only the electrode that has fallen off Replace all the electrodes Nothing as long as the other four leads are reading appropriately Re-apply the electrode that has fallen off 	
<p>6. A nurse has just replaced the electrodes on his or her patient. The nurse knows that proper documentation of electrode replacement should be entered in Cerner in which location:</p> <ol style="list-style-type: none"> Cardiac monitor activity in the Adult ICU Systems Assessments tab Electrodes changed in the Adult ICU Skin- ADL- Nutrition tab Progress note EKG comment in the Adult ICU Systems Assessments tab 	
<p>7. A patient with tremors is on continuous cardiac monitoring and pulse oximetry. The nurse notes that V-tach and low SpO2 alarms are signaling. The nurse promptly checks on the patient and determines that the tremors are interfering with the readings causing false alarms. The nurse corrects the problem by (Select ALL that apply):</p> <ol style="list-style-type: none"> Setting the V-tach alarm priority to informational Stabilize the electrode with a lead wire stress loop near the electrode Increase the SpO2 alarm delay Setting the SpO2 alarm priority to informational 	

<p>8. A patient is admitted with new-onset atrial fibrillation with a heart rate of 140. The nurse adjusts the alarm settings for this patient by changing the atrial fibrillation alarm priority to informational and increases the heart rate limit to 154. The patient undergoes a cardioversion and is now in normal sinus rhythm. The nurse correctly customizes the patient's alarm limits by (Select ALL that apply):</p> <ol style="list-style-type: none">Re-setting the atrial fibrillation alarm priority back to the default settingMaintaining atrial fibrillation alarm priority at informational as the patient may go back into atrial fibrillationRe-setting the heart rate alarm limit back to the default settingMaintaining the heart rate limit because the patient may go back into atrial fibrillation with RVR	
<p>9. The nurse is required to verify and reset, if necessary, the alarm parameters at the beginning of each shift, when the nurse returns from breaks, when the patient is turned or moved, or after patients are transferred. The nurse will document verification of alarm parameters on the EKG strip.</p> <ol style="list-style-type: none">TrueFalse	
<p>10. Proper skin preparation for electrode application includes all of the following <u>except</u>:</p> <ol style="list-style-type: none">Wash the skin with soap and waterWiping the skin with a washclothDate and time electrodeClean skin with alcohol to remove excess oil	

Content Validity Index Table

Item	Expert 1	Expert 2	Expert 3	Mean	I-CVI
1	4	4	4	4	1.0
2	4	4	4	4	1.0
3	4	4	4	4	1.0
4	4	4	4	4	1.0
5	4	4	4	4	1.0
6	4	3	4	3.67	1.0
7	4	4	4	4	1.0
8	4	4	4	4	1.0
9	4	4	4	4	1.0
10	4	4	4	4	1.0

S-CVI= 1.0

Appendix F

October 2017

Green Valley Hospital

Get the Beep Out

Alarm Fatigue Statistics

In 2010, a cardiac patient awaiting a pacemaker died at Massachusetts General Hospital. The patient experienced a dropping heart rate over a period of 20 minutes. Ten nurses were on duty and did not recall hearing the beeps or seeing the visual alarm. In addition, several crises alarms had been turned off the night before. The initial bradycardia alarms had sounded; when the patient's heart rate reached a critical level, the alarm did sound because it had been disabled the night before.

**93% Nuisance Alarm
Rate at GVH**



In 2013, a 17 year old underwent a routine tonsillectomy. The patient was given a fentanyl for pain relief. Over 25 minutes after the administration of fentanyl, the patient's respiratory status declined. The monitoring equipment respiratory alarm had been muted. The patient suffered from an anoxic brain injury and died 15 days later.

A 68 year old patient admitted after esophageal stricture dilation was found unconscious and apneic. The patient sustains an anoxic brain injury and dies after family withdraws life support. The monitors did not alarm which resulted in a delay in resuscitation efforts.

**566 Deaths Linked to
Monitor Alarms**

Gazarian, P. K., Carrier, N., Cohen, R., Schram, H., & Shiromani, S. (2014). A description of nurses' decision-making in managing electrocardiographic monitor alarms. *Journal of Clinical Nursing, 24*, 151-159. doi:10.1111/jocn.12625

Sendelbach, S., & Funk, M. (2013). Alarm fatigue: A patient safety concern. *AACN Advanced Critical Care, 24*(4), 378-386. doi:10.1111/acc.122952

October 2017

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Get the Beep Out

Electrode Application and Skin Preparation



1 CLEAN THE SKIN

Application sites should be clean, dry, and free of lotions. Clean the electrode sites with soap and water. Avoid using alcohol as this can dry out the skin.



2 PREPARE THE SKIN

Excessive hair should be removed from application site. Abrade the skin using a dry wash cloth or gauze. One swipe is all it takes to abrade the skin!



3 APPLY THE ELECTRODE

Avoid pressing on the stud when applying the electrode. Firmly run finger around outside edge to improve electrode adhesion.

DO

- ◆ Change electrodes daily with proper skin prep
- ◆ Chart electrode changes
- ◆ If one falls off, change them all
- ◆ Date/time electrode patch
- ◆ Discontinue telemetry as soon as possible

DON'T

- ◆ Use isopropyl alcohol during skin prep
- ◆ Place over bony areas
- ◆ Place over joints

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Get the Beep Out

Alarm Customization

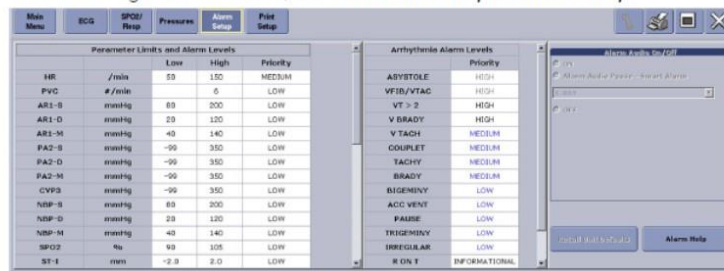
Green Valley Hospital Policy:

- Staff shall verify and reset the alarm parameters:
 - Beginning of shift
 - Returns from breaks
 - Patient is moved or turned
 - Patient is transferred
- Alarm parameters are patient specific.
 - Set 5-10% above and below expected rate.
- Staff shall not silence alarms without first checking patient

Alarm Type	Audio	Visual
High (CRISIS)	Repeats pattern of two 5-beep tones	White text inside a red box
Medium (WARNING)	Repeats pattern of 3-beep tones	Black text inside a yellow box
Low (ADVISORY)	Repeats pattern of 1-beep tone	Black text inside a cyan box
Informational	None	Black text inside a gray box

To adjust the bedside monitor alarm control settings, complete the following procedure:

1. Select the appropriate patient Multi-Viewer window.
2. From the Single Viewer menu, select **Monitor Setup > Alarm Setup**.



Blue text in the Priority column indicate that the parameter has been changed from the default setting.

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Get the Beep Out

Documentation

OP, GUM

DROP, GUM
 Allergies: Allergies Not Recorded
 Advance Directive:

Age: 71 years Height: MRN: 80022010
 Sex: Female Weight: Fin#: 70037225
 CommonWell: Error Attend: Dvnd, Maunch...

Interactive View | I&O

Adult ICU Skin - ADL - Nutrition

- Integumentary
 - Skin Abnormality
 - Incision/Wound Assessment/Tx
 - Incision/Wound Care
 - Surgical Drains/Tubes
- Safety
- Activity ADLs
- Nutrition ADLs
- Hygiene ADLs**
- Belongings
- Braden Assessment
- Fall Risk Scale Morse

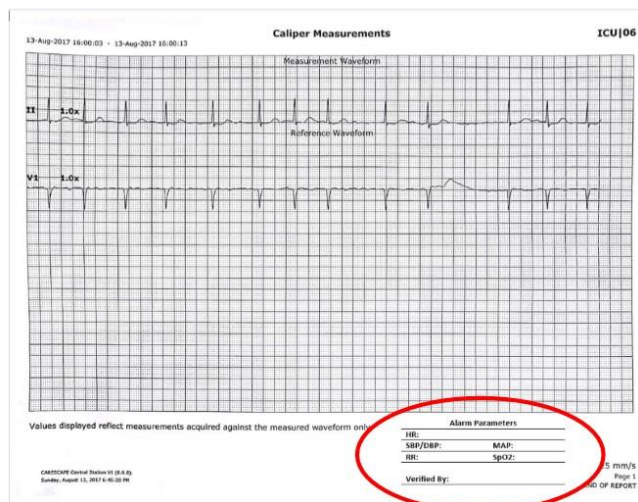
Adult ICU Lines - Devices

- Intake And Output
- Adult Education

Find Item	Critical	High	Low	Abnorm
Hygiene ADLs				
Personal Care Provided				
Perineal Interventions				
Urinary Catheter Care Done				
Other Hygiene Options				
Elimination Assistance Offered				
Bowel Movement Last Date				
Linen Change				
Gown Change				
Electrodes Changed				Electrodes Changed <input checked="" type="checkbox"/>
Braden Assessment				Yes
Sensory Perception				No
Moisture				

Daily electrode changes should be documented in Cerner under the Adult ICU Skin- ADL- Nutrition tab > Hygiene ADLs.

Reminder: Skin prep should also be documented under Personal Care Provided.



Alarm parameter verification should be documented with each telemetry strip interpretation from the central monitor.

October 2017

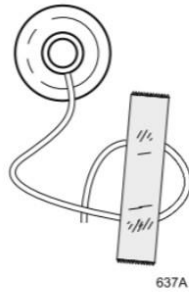
Green Valley Hospital

Get the Beep Out

Decrease False Alarms & Artifact related to Motion



Increasing the SpO2 alarm delay will allow the monitor additional time to sense the patient's oxygen before alarming. To change the delay setting from bedside monitor: SpO2 settings → SpO2 limits → Alarm Delay in Secs.



Stabilize the electrode and leadwire with a leadwire stress loop near the electrode. Tape the stress loop to the patient. A secured stress loop prevents leadwire rotation about the electrode snap, leadwire tugging at the electrode, and ECG artifact.

Appendix H

Action Plan

Type	What	How	Who	When	Where	Why
Strategy	Reduce nuisance alarms in ICU	<ul style="list-style-type: none"> • Eliminate duplicative/inactionable alarms in default parameters • Change electrodes daily with proper skin prep • Educate nursing staff to customize patient alarm parameters 	<ul style="list-style-type: none"> • Practice Mentor • Manager • Director • Monitor Superuser 	November 1 st through November 18 th	ICU	A bundled approach has shown to decrease the number of false and inactionable alarms.
People Organization	Practice site	Create an alarm management team	<ul style="list-style-type: none"> • Practice Mentor • Manager • Director • Monitor Superuser 	Ongoing	Practice site	An interdisciplinary approach is necessary to implement a bundled approach to reducing

						alarms.
Process	Work with members of the alarm management team to implement bundled approach	<ul style="list-style-type: none"> • Monitor superuser will assist with adjusting default alarm parameters • Manager, Director, and Practice mentor will help with education in electrode placement and alarm customization. 	<ul style="list-style-type: none"> • Practice Mentor • Manager • Director • Monitor Superuser 	November 1 st through November 25 th	ICU	An interdisciplinary approach is necessary to implement a bundled approach to reducing alarms.
Technology	GE Dash 5000 Monitor	<ul style="list-style-type: none"> • Adjust default alarm parameters 	<ul style="list-style-type: none"> • Monitor Superuser 	November 1 st	ICU	To eliminate duplicative/ inactionable alarms

Appendix I

Project Schedule

Project Schedule for Alarm Management									
Tasks	Who	Hours	Start	End	11/1	11/8	11/15	11/22	11/29
<ul style="list-style-type: none"> • Planning Phase 	<ul style="list-style-type: none"> • Practice Mentor • Manager • Director • Monitor Superuser 	144	7/5	10/27					
<ul style="list-style-type: none"> • Change Default Alarm Settings 	<ul style="list-style-type: none"> • Practice Mentor • Manager/Director • Monitor Superuser 	1	11/1	11/1					
<ul style="list-style-type: none"> • Extract & Analyze Alarms • Pre- intervention Chart Audits- Electrodes • Pre-test on Alarm Management 	<ul style="list-style-type: none"> • Practice Mentor • Manager • Director 	40	11/5	11/11					
<ul style="list-style-type: none"> • Alarm Management Education • Post-test on Alarm Management 	<ul style="list-style-type: none"> • Practice Mentor • Manager • Director 	15	11/12	11/18					
<ul style="list-style-type: none"> • Extract & Analyze Alarms • Post-intervention chart audits- Electrodes & Alarm verification 	<ul style="list-style-type: none"> • Practice Mentor • Manager • Director 	40	11/18	11/25					
<ul style="list-style-type: none"> • Data Analysis 	<ul style="list-style-type: none"> • Practice Mentor 	15	11/26	12/5					