

2015

Alarm Safety in a Regional Neonatal Intensive Care Unit

Piper Probst
Walden University

Follow this and additional works at: <https://scholarworks.waldenu.edu/dissertations>

 Part of the [Nursing Commons](#)

This Dissertation is brought to you for free and open access by the Walden Dissertations and Doctoral Studies Collection at ScholarWorks. It has been accepted for inclusion in Walden Dissertations and Doctoral Studies by an authorized administrator of ScholarWorks. For more information, please contact ScholarWorks@waldenu.edu.

Walden University

College of Health Sciences

This is to certify that the doctoral study by

Piper Probst

has been found to be complete and satisfactory in all respects,
and that any and all revisions required by
the review committee have been made.

Review Committee

Dr. Mary Tilbury, Committee Chairperson, Health Services Faculty

Dr. Eric Anderson, Committee Member, Health Services Faculty

Dr. Joanne Minnick, University Reviewer, Health Services Faculty

Chief Academic Officer

Eric Riedel, Ph.D.

Walden University

2015

Abstract

Alarm Safety in a Regional Neonatal Intensive Care Unit

by

Piper A. Probst

MSN, University of Michigan, 1998

BSN, Michigan State University, 1992

Project Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Nursing Practice

Walden University

October 2015

Abstract

Alarm fatigue is a practice problem that applies to hospitalized patients and the nurses who care for them. Addressing alarm fatigue is important to promote alarm safety and to decrease the risk of patient harm or death. The purpose of this study was to decrease alarm fatigue and improve alarm safety in a regional neonatal intensive care unit (RNICU). Guided by the conceptual model for alarm fatigue and alarm safety, this study addressed whether or not alarm management protocols designed to decrease false and nuisance alarms in the physiological monitoring of neonates improve alarm safety via decreased alarm burden and alarm fatigue as evidenced by statistically significant reductions in false and nuisance alarms. A quantitative, time series quasi-experimental design was used with 4 waves of data collection. One wave was baseline data collected preintervention, and 3 waves of data were postprotocol implementation to obtain an initial indication of sustainability. Alarm observation data collection sheets were developed and used to track numbers and types of alarms pre- and post-protocol implementation. The data analysis showed statistically significant decreases in both false alarms and nuisance alarms related to the physiological monitoring protocol and lead changing protocol. Overall, high protocol adherence was noted, and the total number of alarms per hour per bed was reduced by 42% ($p < .001$), 46% ($p < .001$), and 50% ($p < .001$) from baseline at Weeks 2, 4, and 6, respectively. Implications from this study include impact on practice and policy, direction for future study, and a call for social change to promote alarm safety in the care of neonates.

Alarm Safety in a Regional Neonatal Intensive Care Unit

by

Piper A. Probst

MSN, University of Michigan, 1998

BSN, Michigan State University, 1992

Project Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Nursing Practice

Walden University

October 2015

Dedication

This work is dedicated to Elgin and Eli Probst, my teenaged sons who have been extremely supportive and understanding of my DNP studies. I believe they have gained an increased appreciation of the importance of homework, learned to become a bit more independent, and now appreciate that learning is truly a lifelong endeavor. They are wonderful sons, I am blessed to have them, and I love them beyond measure.

Acknowledgments

First and foremost I would like to acknowledge my husband, DeWayne. Thank you for all you have done to support me in this endeavor. I am looking forward to saying “yes” to date nights again instead of “I’m sorry. I need to write a paper.” I would also like to acknowledge my mom, Sandra Green. Thank you for all of your support and encouragement.

I would also like to acknowledge neonatal nurse experts Kathleen Marble, MSN, RNC-NIC and Sarah Collins, BSN, RNC-NIC. This work would not have been possible without you and your nursing team. Thank you for your time and contributions. You make a difference every day in the work you do.

Lastly I would like to acknowledge my DNP project chairperson and committee members, Mary Tilbury, Eric Anderson and Joanne Minnick. Thank you to Dr. Anderson and Dr. Minnick for serving on my project committee. Thank you to Mary for being my project chair and for all you have done to bring this project to fruition in a timely manner while providing guidance and expertise.

Table of Contents

List of Tables	iv
List of Figures	v
Section 1: Overview of the Evidence-Based Project	1
Introduction.....	1
Problem Statement	1
Purpose Statement and Project Objectives/Aims.....	2
Significance/Relevance to Practice.....	3
Project Question.....	3
Hypotheses and Null Hypotheses	3
Evidence-Based Significance of the Project	4
Definitions of Terms.....	5
Summary	5
Section 2: Review of Scholarly Evidence.....	6
Overview of the Literature.....	6
Literature Search.....	6
Summary of Literature Review.....	7
Alarm Notification Systems.....	8
Review of Two Studies Focused on Alarm Fatigue	9
Key Evidence for the EBP Project.....	11
Overview of Theories Considered for Use in Studying Alarm Associated Practice Problems.....	12

Conceptual Model.....	13
Summary.....	16
Section 3: Approach.....	18
Project Design/Methods.....	18
Setting and Sampling.....	18
Data Collection.....	19
Study Interventions/Protocols.....	20
Data Analysis.....	23
Project Evaluation Plan.....	24
Summary.....	24
Section 4: Findings, Discussion, and Implications.....	25
Summary and Evaluation of Findings.....	25
Discussion.....	29
Implications.....	30
Project Strengths and Limitations.....	33
Analysis of Self.....	34
Summary and Conclusions.....	36
Section 5: Scholarly Product – Sample Paper for Presentation.....	38
Introduction.....	38
The Problem.....	38
Purpose Statement and Project Objectives/Aims.....	39
Significance/Relevance to Practice.....	40

Project Question.....	40
Hypotheses and Null Hypotheses	40
Evidence-Based Significance of the Project	41
Definition of Terms.....	42
Conceptual Model.....	42
Project Design/Methods.....	45
Setting and Sampling	45
Project Evaluation Plan.....	46
Findings and Discussion	47
Implications.....	48
Summary and Conclusions	51
References.....	52
Appendix A: Alarm Definitions for Conceptual Model	56
Appendix B: Summary of Analyzed Articles	58
Appendix C: Room Numbering for Data Collection	61
Appendix D: Project Assistant Orientation.....	62
Appendix E: Alarm Observation Data Collection Sheet – Preintervention.....	64
Appendix F: Alarm Observation Data Collection Sheet – Postintervention	65
Appendix G: Range, Median, and Mode for Alarm Observation Data	66

List of Tables

Table 1. Monitoring Parameter EBP Protocol	21
Table 2. Electrode Lead/Pad and Probe Changing EBP Protocol	22
Table 3. Alarm Data and Protocol Adherence	28

List of Figures

Figure 1. Conceptual model for alarm fatigue and alarm safety.....13

Figure 2. Neonatal physiological monitoring alarms28

Section 1: Overview of the Evidence-Based Project

Introduction

Alarm fatigue is a pressing national issue that compromises patient safety (Cvach, 2012; The Joint Commission [TJC], 2013). To the degree that alarm fatigue can be prevented, alarm safety can be promoted and patients will be safer. Many types of equipment used in hospitals have alarms intended to ensure safer patient care. The alarm is supposed to sound when the patient needs clinical care and intervention. However, the reality is that alarms are often not clinically relevant. They do not help health care workers know when care and intervention are needed. All too frequently, the alarms are false and nuisance alarms; these nonclinically relevant alarms are associated with alarm fatigue and desensitization in clinicians, which have been linked to patient harm and death (TJC, 2013).

There is increasing awareness of the potential hazards associated with alarms with research showing “. . . 72%–99% of clinical alarms are false” (American Association of Critical Care Nurses [AACN], 2013, p. 378). Some sources also report that alarms are the number one technical hazard for patients (AHC Media, 2013). Specific to the growing body of evidence and reports of patient harm and death, TJC introduced a new National Patient Safety Goal (NPSG) in July of 2014. NPSG.06.01.01 reads, “Improve the safety of clinical alarm systems” (TJC, 2014).

Problem Statement

Alarm fatigue is a problem that creates risk and compromises patient safety. TJC now has language to address alarm safety, and the AACN recommends specific strategies

or interventions that can reduce the prevalence of alarms that do not require clinical intervention. As indicated earlier, alarms that do not require clinical intervention are commonly referred to as false alarms and nuisance alarms. Decreasing these types of alarms can reduce the risk for or amount of alarm fatigue and subsequently decrease the risk of a serious safety event caused by or related to a failed or delayed response to a clinical alarm. This problem is relevant to hospitalized patients of all ages. The focus area for this study was alarm fatigue and alarm safety as it relates to the physiological monitoring of neonates in an intensive care environment.

Purpose Statement and Project Objectives/Aims

The purpose of this study was to decrease alarm fatigue and improve alarm safety in the RNICU using evidence-based practice (EBP) intervention protocols.

The specific aims or objectives of this study were as follows:

1. Determine whether the use of five sets of specific options for physiological monitoring would significantly decrease the prevalence of nuisance alarms; this is the monitoring parameter EBP protocol.
2. Determine whether the implementation of a lead changing procedure would significantly decrease the prevalence of false alarms; this is the electrode lead and probe changing EBP protocol.
3. Determine whether the above interventions could be sustained.
4. Examine relationships of alarm fatigue and alarm-safety-related concepts.

Significance/Relevance to Practice

The significance to practice is the potential to create an environment where all or most alarms are clinically relevant and thereby create a sense of urgency in response.

The significance to patient outcomes is the decreased risk of delayed or failed response to an alarm that could result in poor patient outcomes up to and including patient death.

Project Question

EBP projects often frame the question of interest in a “PICO” format where “P” is the population of interest, “I” is the intervention, “C” is the comparison of the intervention, and “O” is the outcome (Grove, Burns & Gray, 2013). The PICO question for this project was:

Related to the physiological monitoring of neonates, can alarm management protocols designed to decrease false and nuisance alarms (as compared with no protocols) improve alarm safety via decreased alarm burden and alarm fatigue as evidenced by statistically and clinically significant reductions in false and nuisance alarms?

Hypotheses and Null Hypotheses

Hypotheses specific to the study were as follows:

- The neonatal electrode lead changing protocol will decrease the frequency of false alarms.
- The neonatal monitoring parameter protocol outlining use of specific default monitoring parameters will decrease the frequency of nuisance alarms.

Null hypotheses specific to the study were as follows:

- The neonatal lead changing protocol will not decrease the frequency of false alarms.
- The neonatal monitoring parameter protocol outlining use of specific default monitoring parameters will not decrease the frequency of nuisance alarms.

Evidence-Based Significance of the Project

Both estimates and actual data on the prevalence of alarms are in the literature; two specific examples of actual data are shared here. In one study of physiological alarm load in a medical-surgical setting, researchers found the following: “The average number of alarms per patient was 69.7 alarms. When this is adjusted to the duration of monitoring, an average per patient, per day rate was 95.6 alarms” (Gross, Dahl, & Nielsen, 2011, p. 29). In a study related to physiological alarms on a 15 bed medical progressive care unit, researchers found the following: “During an 18-day period, the number of alarms totaled 16,953, equating to 942 alarms per day” (Graham & Cvach, 2010, p. 32). As noted previously, TJC has regulatory language, and the AACC recommends specific strategies or interventions that can reduce the prevalence of alarms that do not require clinical intervention. Alarms that do not require clinical intervention are commonly referred to as false alarms and nuisance alarms. Decreasing these alarms can reduce the risk or amount of alarm fatigue and subsequently decrease the risk of a serious safety event caused by or related to a failed or delayed caregiver response to a clinical alarm. In addition, per TJC’s Sentinel Event database, “. . . there have been 98 alarm-related events between January 2009 and June 2012. Of the 98 reported events, 80 resulted in death, 13 in permanent loss of function . . .” (2013, p. 1). Health care views any serious safety event

as one too many and advocates for proactive measures to ensure safety and prevent reoccurrence of similar events.

Definitions of Terms

Multiple key terms have been introduced thus far, and some are defined here. An *alarm* is defined as “a signal (as a loud noise or flashing light) that warns or alarms” (Merriam-Webster, n.d.). A *clinical alarm* is a signal intended to provide warning in a clinical or patient care environment. A *false alarm* is defined as “an alarm that is set off needlessly; causing alarm or excitement that proves to be unfounded” (Merriam-Webster, n.d.). A *nuisance alarm* is when “monitor parameter thresholds are set too tight; true but clinically insignificant” (Cvach, 2012, p. 269). *Alarm fatigue* is “when a caregiver can become overwhelmed by a large number of clinical alarms such that alarm-related events can be missed or ignored” (Keller, 2012, p. 589). *Alarm fatigue* has also been defined as “the lack of response due to excessive numbers of alarms resulting in sensory overload and desensitization” (Cvach, 2012, p. 269). Additional definitions are provided in Appendix A.

Summary

Alarm fatigue is a national level issue, and alarm safety is the desired goal in the hospital setting. This is true for patients of all ages. The purpose of this EBP study was to decrease alarm fatigue and improve alarm safety in a RNICU.

Section 2: Review of Scholarly Evidence

Overview of the Literature

As noted earlier, a growing body of evidence gives merit to the alarm fatigue practice problem and supports its relevance to nursing. Cvach (2012), in her article entitled “Monitor Alarm Fatigue; An Integrative Review,” provided an overview of evidence. Her review included consideration of 177 abstracts, which led to the full review of 85 articles. Cvach organized the research findings into the following major theme areas:

1. Excessive alarms and effects on staff
2. Nurse’s response to alarms
3. Alarm sounds and audibility
4. Technology to reduce false alarms
5. Alarm notification systems (2012, p. 270)

Cvach further recognized two non-research areas for evidence related to alarm fatigue.

One area is “Strategies to Reduce Alarm Desensitization” (2012, p. 272). The other area is “Alarm Priority and Notification Systems” (2012, p. 272).

Literature Search

The focus of this EBP project was primarily related to the first major theme area identified by Cvach (2012), excessive alarms and “Strategies to Reduce Alarm Desensitization” (p. 272). Alarm notification systems were also of interest early on in this EBP project. The literature search was done in collaboration with medical librarians

and included both MEDLINE and CINAHL data bases. Key words and phrases used in the search were: *alarm safety, alarm fatigue, clinical alarms, physiological alarms, false alarms, nuisance alarms, and clinically relevant alarms*. The Boolean search string was: *alarm fatigue OR clinical alarms AND/OR stress OR mental fatigue OR fatigue*. The search was restricted to materials in English. The initial literature search resulted in more than 40 sources of evidence being pulled for further review. The majority of the literature pulled was generated in the United States; however, there were also articles with authors from China, the United Kingdom, Canada, Germany, and the Netherlands indicating alarm safety is a concern on an international level.

The Melnyk and Fineout-Overholt Strength of Evidence Rating Scheme (2011) was used to rate the evidence initially, and later the AACN) levels were also used. The AACN levels allowed for the inclusion of manufacturer information, which can be relevant for monitoring equipment with alarms. A literature review table is included in Appendix B. Following are a summary of the literature reviewed, information related to alarm notification systems, a review of two studies focused on alarm fatigue, and a review of evidence that directly led to the interventions for this project.

Summary of Literature Review

Level 3, controlled trial, nonrandomized studies are limited. Most evidence or research in the area of alarm safety and alarm fatigue falls into Level 5, or systematic reviews of descriptive and qualitative studies; Level 6, or single descriptive or qualitative studies; and Level 7, or expert opinions. Of the Level 3 studies reviewed, the aim of the study was not related to reducing alarm fatigue associated with false and nuisance alarms

(Bellomo et al., 2012). Two Level 5 studies support EBP project protocol interventions to reduce or eliminate false and nuisance alarms (Cvach, 2012; Konkani, Oakley, & Bauld, 2012). There is one Level 6 study with specific interventions that were trialed on a medical progressive care unit and associated with a 43% reduction in critical monitor alarms to also support the protocol (Graham & Cvach, 2010).

Alarm Notification Systems

As noted previously, early on in the current project development, alarm notification systems were of interest as a way of decreasing alarm fatigue. Cvach, Frank, Doyle, and Stevens (2013), in their article entitled “Use of Pagers with an Alarm Escalation System to Reduce Cardiac Alarm Monitor Signals,” described their work at Johns Hopkins Hospital to use technology to safely decrease alarm signals and thus reduce alarm fatigue. More specifically, they optimized the use of clinical technology and the interoperability between cardiac monitoring equipment and nurse communication devices to create an alarm escalation algorithm which essentially triaged and routed alarm signals based on computer program logic. Using delays to decrease the number of alarms was of particular interest. Cvach et al. (2013) shared the following:

. . . non-crisis, high-priority alarm conditions are sent to the nurse’s acknowledgement pager only if the alarm persists longer than 60 seconds. This time frame was selected by examining the units’ alarm duration logs, which indicated that approximately 90% of alarm conditions self-correct in less than 60 seconds (p. 3).

As this type of alarm safety strategy is very technology dependent, it is not a readily viable solution unless the interoperability of equipment is available. As this was not the case for the selected NICU, this type of alarm safety intervention was not explored further for inclusion in the study. However, it was noted that the use of the alarm escalation algorithm delay function was effective in decreasing nuisance alarms (Cvach et al., 2013).

Review of Two Studies Focused on Alarm Fatigue

In the article entitled “Physiologic Monitoring Alarm Load on Medical/Surgical Floors of a Community Hospital,” researchers Gross, Dahl, and Nielsen (2011) discuss alarm fatigue and share their finding from a retrospective study of alarm frequency. Their intent was to learn more information about alarms in the medical-surgical setting; subsequently their study was conducted related to 79 medical-surgical patient beds in a community hospital. The data were collected from April 2009 to January 2010 for more than 4000 patients that underwent monitoring during that time with alarms that had equipment default settings as an indication of normal. Alarms were put into categories such as critical alarms (i.e. those that could indicate a life threatening event) and high priority alarms (i.e. vital signs outside of normal or acceptable limits or cardiac rhythm abnormalities). Looking at the full set of alarm data, they determined the following alarm frequency rates: “The average number of alarms (all severities) per patient was 69.7 alarms. When this is adjusted to the duration of monitoring, the average per patient, per day rate was 95.6 alarms” (Gross, Dahl, & Nielsen, 2011, p. 29). The researchers then did further analysis on a small sub-set of patient alarm data ($n = 30$) to determine

accuracy of alarms (i.e., alarms were true) in the medical-surgical setting. They determined from this more in depth analysis that included correlation of alarm data with the clinical record that 34% of critical alarms were true, and 63% of high priority alarms were true. The researchers had several conclusions from this study and analysis, including the observation that default or standard critical care alarm settings seem “to be too sensitive for the subacute care areas of the hospital” (Gross, Dahl, & Nielsen, 2011, p. 29). Gross et al. further concluded that small changes in alarm parameters could have a positive impact on decreasing alarms that required no clinical action (p. 29).

In the article entitled “Monitor Alarm Fatigue: Standardizing Use of Physiological Monitors and decreasing Nuisance Alarms,” nurse researchers Graham and Cvach (2010) discussed concerns with alarm fatigue and share their findings from a unit based quality improvement project where several “small tests of change” were implemented with the intent to improve alarm safety. Part of their goal was to eliminate or decrease non-actionable alarms, such as nuisance and false alarms, and only have alarms that are actionable (2010, p. 31). The unit used for this project was a 15-bed medical progressive care unit which hosts patients that frequently have changes in vital signs and other physiological measures (Graham & Cvach, 2010, p. 29). The types of alarms on the unit were organized into two categories: patient status alarms, which included four types of alarms that indicate a patient’s physiologic status; and system status alarms which sound for electrical or mechanical issues. The alarms used for preintervention and postintervention measures included two patient status alarms, crisis and warning; and system warning alarms. The interventions or “small tests of change” to improve alarm

safety included nurse training, revisions to default alarm settings, identification and elimination of duplicate alarms, and the addition of new software that allows staff to see and act upon alarm information sooner (Graham & Cvach, 2010, pp. 31–32). The result of this unit based quality improvement project was “a 43% reduction in critical physiological monitor alarms” (Graham & Cvach, 2010, p. 33).

Key Evidence for the EBP Project

A key source of evidence that supports the basis of the interventions for this EBP project is the AACN’s clinical practice guideline on Alarm Management. Per the AACN, (a) alarms should be customized to meet the needs of the patients, (b) delay and threshold settings should be used with pulse oximetry, (c) electrodes should be changed daily, and (d) disposable pulse oximetry probes should be replaced as needed to ensure proper function (2013, p. 1). Related to the electrode changes in neonates, consideration was given to skin integrity. Further literature search was conducted related to cardiac electrode changes for neonates, but no published information was found. Additionally, contact was made with the National Association of Neonatal Nurses (NANN) and the Association of Women’s Health, Obstetric and Neonatal Nurses (AWHONN). While both have indicated some work being done in the area of alarm fatigue and alarm safety, neither NANN nor AWHONN were able to offer neonatal standard of care guidelines or position statement types of resource related to clinical alarms or electrode changes at this time. Subsequently, expert input was sought out. Per consultation with a board certified neonatal clinical nurse specialist with 30 years of experience, routine changes of electrodes are appropriate, but the frequency needs to be every two or three days related

to neonatal skin integrity (K. Marble, personal communication, August, 2014). For the neonate in a high humidity environment with small electrodes, it would be appropriate to change electrodes every third day (K. Marble, personal communication, August, 2014). For the neonate in a low humidity environment with large electrodes, it would be appropriate to change the electrodes every second day (K. Marble, personal communication, August 2014).

In brief, while a notable quantity of evidence does exist, it is at variable levels of strength and not specific to the neonatal care environment. However, the evidence does provide interventions shown to be effective in reducing or eliminating false and nuisance alarms. This evidence was applied to a neonatal ICU setting in the form of EBP intervention protocols with the intent to decrease alarm fatigue and improved alarm safety.

Overview of Theories Considered for Use in Studying Alarm Associated Practice Problems

Despite search efforts that included enlisting the expertise of a medical librarian, there was no success in locating a theory specific to alarm fatigue or alarm safety. However, given the many themes or areas of evidence related to alarm fatigue, various theories or models could be given consideration as a framework for a project or for studying an alarm associated practice problem. For example, if the focus of the project was changing nurse behaviors related to alarms, a change theory such as Lewin's Planned Changed Theory could have been used (McEwen & Wills, 2011, p. 337). Another option might be to adapt Prochaska's and Velicer's Transtheoretical Model of Health Behavior

Change; consideration could be given to and changes planned related to the six stages of change: precontemplation, contemplation, preparation, action, maintenance, and termination. The Transtheoretical Model might also be particularly helpful in studying how to sustain desired nursing behaviors related to alarms (1997, p. 38). However, if the focus of the study was the impact of alarms on nurses or patients, then Kolcaba's middle-range Comfort Theory (2003) or Lenz, Pugh, Milligan, Gift, and Suppe's middle-range Theory of Unpleasant Symptoms (TUS) (1997) could be applicable. However, the selection of an existing theory to serve as a project or study framework is not the only option. A project or study framework can come from "synthesizing a framework from research findings" and/or from "proposing a framework from clinical practice" (Grove, Burns & Gray, 2013, p. 130).

Conceptual Model

For this scholarly project studying alarm fatigue and alarm safety in the neonatal intensive care unit, a conceptual framework specific to alarm fatigue and alarm safety is helpful and is feasible based on knowledge of clinical practice. Not only does the development of this framework serve as a more logical and pragmatic approach to the study, it offers enhanced clarity and consistency. It does not require a crosswalk or in depth explanations as to how the alarm related concepts and study interventions fit within a current theory. Definitions for the conceptual model are provided in Appendix A. Relational statements, assumptions, and a figure of the developing model are included here.

Relational Statements:

1. Alarm fatigue (AF) exists if and only if there is alarm burden (AB) in time.
2. Nuisance alarms (NAs) have a positive correlation with alarm burden (AB) and alarm fatigue (AF).
3. False alarms (FAs) have a positive correlation with alarm burden (AB) and alarm fatigue (AF).
4. Work capacity has a negative correlation with process/practice variations.
5. Alarm fatigue has a positive correlation with alarm risk behaviors (ARBs) (i.e., delayed response, no response, silencing alarm without checking patient, turning off monitoring equipment).
6. Alarm fatigue has a negative correlation with alarm safety (AS).
7. As the percentage of clinically relevant alarms (CRAs) increases, alarm safety (AS) increases.

Assumptions for the model include the following:

1. Alarm workload exists in a dynamic environment and is a combination of all alarms (i.e., clinically relevant alarms, nuisance alarms, and false alarms).
2. Alarm burden exists and occurs when alarm workload exceeds work capacity.
3. Alarm fatigue exists and is a product of alarm burden over time; it is a subjective experience.
4. Decreasing alarm burden and alarm fatigue improves alarm safety.
5. The higher the percentage of alarms that are clinically relevant, the higher the level of alarm safety.

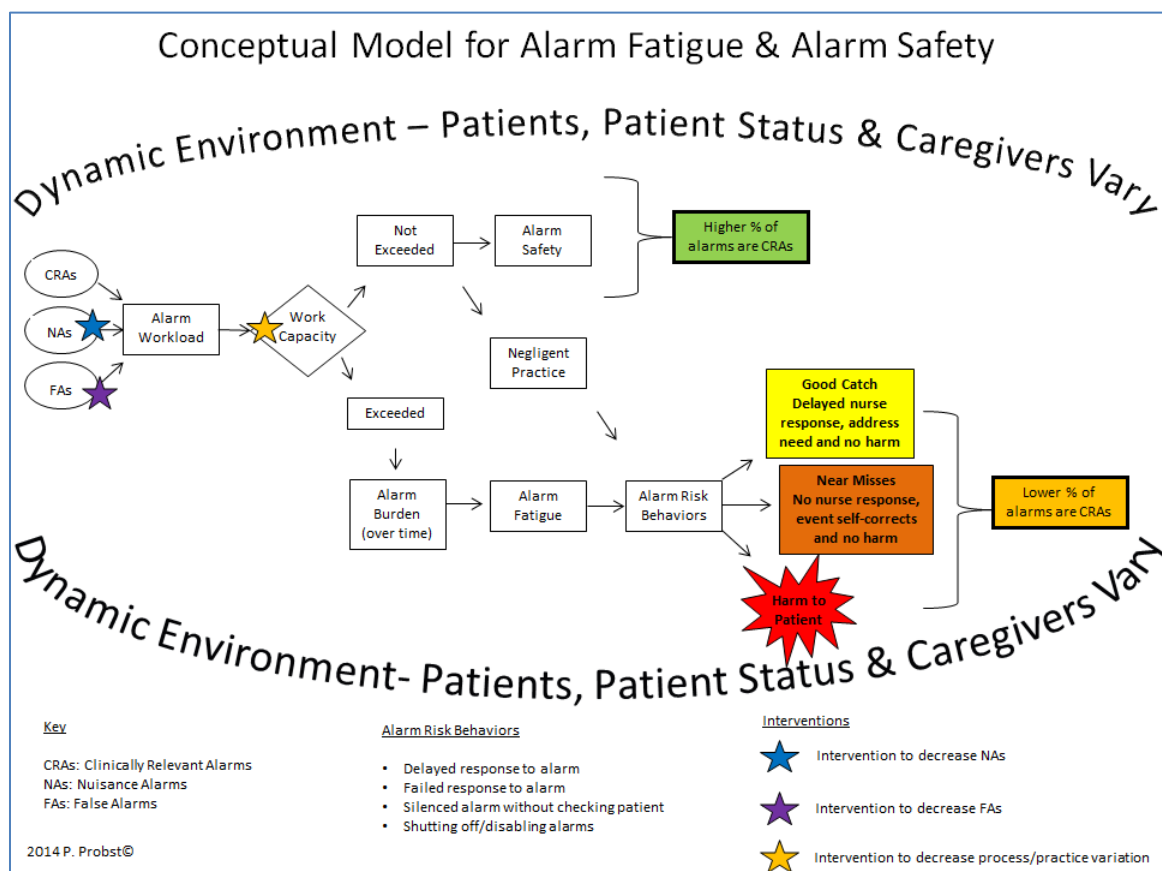


Figure 1. Conceptual model for alarm fatigue and alarm safety.

Per the model, alarms happen in a dynamic clinical environment where patients, patients' statuses, and caregivers such as nurses and technical support persons vary. Clinically relevant alarms, nuisance alarms and false alarms combine to create an alarm workload. If the alarm workload does not exceed the work capacity of the caregivers, alarm safety is likely. A caveat to this is if caregivers opt not to respond to alarms even though they have the ability to do so; this situation would be considered negligent practice. However, if the alarm workload exceeds the work capacity of the caregivers, this creates an alarm burden which over time results in alarm fatigue. Caregivers faced with alarm fatigue are subject to alarm risk behaviors such as delayed or failed response

to alarms, silencing alarms without checking the patient, and shutting off or disabling an alarm. Alarm risk behaviors can result in different outcomes. The caregiver could eventually get to the alarm; there is a good catch and no harm to the patient. The caregiver could not get to the alarm; however, the situation corrects itself. There is a near miss, but no harm to the patient is realized. Lastly, the caregiver could not get to an alarm, a serious event happens, and there is harm to the patient. Related to this overall situation, the model indicates that alarm safety is more likely when there a high percentage of alarms that are clinically relevant. Conversely, if there is a low percentage of alarms that are clinically relevant, alarm safety is less likely.

Summary

Weaknesses in the literature include limited randomized control trials (RCTs) and few clinical RCTs; however, there are challenges to alarm studies of this nature in the hospital environment. One challenge includes the ability to control for all variables. Additionally, it would be inappropriate and unethical to design studies where one group was monitored and the other was not. Published evidence was not located for cardiac electrode changes for neonates. Another weakness noted in the literature was the general lack of conceptual or theoretical frameworks, and when there was note of a framework, it was not specific to alarm fatigue or alarm safety.

Strengths in the literature include the quantity of evidence for review, the amount of evidence that supports the importance/merit of the problem, the diversity of disciplines contributing to the evidence and the availability of several integrated reviews. There is also specific evidence for interventions to decrease false alarms and nuisance alarms. In

addition, expert opinion was available to help apply EBP interventions to promote alarm safety for neonates.

Section 3: Approach

Project Design/Methods

This was a scholarly project using what is known about management of physiological alarms used for adults and applying that evidence to managing physiological alarms for neonates. A quantitative, time-series quasi-experimental design was employed to facilitate study aims. The two independent variables in this study included (a) intervention of implementing the monitoring parameter EBP protocol and (b) intervention of implementing an electrode lead and probe changing EBP protocol. The following dependent variables were measured: (a) number of nuisance alarms and (b) number of false alarms.

Human Subjects

There were no human subjects for this EBP project. The subject of inquiry was physiological monitoring equipment alarms. Alarm sampling and measures taken to protect any data potentially related to a given patient are detailed below in the Setting and Sampling section.

Setting and Sampling

An RNICU was selected for several reasons. As this is a critical care unit, physiological monitors with alarms were routinely used. The average daily census ensured availability of patients undergoing monitoring for alarm data collection purposes. Given the physical set-up of the unit, monitoring equipment could easily be observed by project assistants for data collection purposes. The staff has a history of being engaged

and receptive to change and efforts to improve quality of care; these factors were beneficial when considering the introduction of the EBP protocol interventions.

Sampling of alarm frequencies and types was done. Related to the sampling of alarms, each of the 35 occupied beds within the RNICU was observed by the project assistants in 15-minute increments to collect data on alarm frequency and types. These 15-minute observations were done during blocks of time at different times of the day and night on different days of the week to ensure that data collected represented both day and night shifts as well as week and weekend days. Observation data were used to calculate averages. Block times were up to 5 hours to allow for 16 beds to be observed and for transitions between observations. For the purposes of this study, the bed assignment numbers used for admission and electronic medical record purposes were not referenced in the data collections, as this could be viewed as identifying data. Beds were assigned numbers 40 to 74 for the purposes of tracking observation of all 35 beds (Appendix C). Data were collected in four waves: Wave 1: preinterventions, Wave 2: 2 weeks after initial interventions, Wave 3: 2 weeks after second interventions (change in monitoring protocol related to saturation-seconds), and Wave 4: 4 weeks after second interventions.

Data Collection

Two part-time project assistants were recruited for data collection, data entry, and other assistive support for the project. Two part-time assistants also allowed flexible scheduling to meet data collection needs on different days and nights. They were provided with orientation and training by the RNICU nurse educator. Orientation included introduction to the neonatal intensive care team and environment as well as

basic education on the clinical monitoring equipment and alarms (Appendix D). Training included use of the data collection tools that were used to collect preintervention and postintervention alarm data (Appendices E and F). The only difference in the tools was that the one used for postintervention data collection also collected data on the independent variables. Effectiveness of training was evaluated by having the project assistant practice data collection at the same time the RNICU nurse educator collected data for the same beds. Their data collection results were compared. Practice continued until each assistant demonstrated competence in data collection as evidenced by correct identification of physiological alarm type and category.

The other data that was considered in the study analysis was a report from the company that makes the physiological monitoring equipment used in the RNICU. This automated report shows a full week of data including the frequency of alarms, some categorization of alarms, and an average daily rate of alarms. This report was unfortunately not as helpful as initially thought. One limitation of the reports was the lack of census information. Subsequently, it is not feasible to determine if changes in the number of alarms were related to changes in the number of occupied beds. Additionally, while the report does give numbers of parameter alarms, nuisance alarms cannot be differentiated from clinically relevant alarms.

Study Interventions/Protocols

As previously noted there were two specific interventions or protocols for this EBP study which meet or exceed the standard of care for the physiological monitoring of neonates. One protocol was related to physiological monitoring parameters (Table 1) and

one was related to electrode and probe changes. Prior to the study, the RNICU did not use protocols of this nature. Nurses in the RNICU were instructed on the use of these protocols prior to implementation.

Table 1

Monitoring Parameter EBP Protocol

Profile	Oxygen saturation	HR	RR	BP
	% Saturation			S/D/M
	Sat-Sec buffer			
	Setting*			
<1600 gms With O2 therapy	89-95 15-30 Sat-Sec	80-220	1-90	S 40-100 D 15-60 M 25-70
>1600 gms With O2 therapy Without PPHN and without cardiac	88-97 15-30 Sat-Sec	80-220	1-80	S 40-100 D 20-60 M 30-70
PPHN Persistent Pulmonary Hypertension of the Newborn	94-101 15-30 Sat-Sec	80-220	1-80	S 40-100 D 20-60 M 307-0
Cardiac (Congenital)	75-101 15-30 Sat-Sec	75-220	1-80	S 40-100 D 20-60 M 30-70
Room Air	89-101 15-30 Sat-Sec	80-220	1-80	S 40-100 D 20-60 M 30-70

Notes. The above parameters apply to any infant receiving oxygen regardless of how it is being delivered. Any change from the above monitoring parameters requires a physician order. *Sat-Sec Buffer Setting: This uses a mathematical equation that gives a set

amount of buffer called ‘Saturation Seconds.’ The further an SP02 alarm goes below its low limit, the faster it uses this buffer up, and when the SP02 limit goes back in range, it begins to build the buffer again. The alarm will only sound when the buffer is used up. This is essentially a sophisticated delay functionality, which is supported by the ANCC guidelines (2013). For initial protocol implementation, the sat-sec buffer was set at 15; after 2 weeks it was increased to 30 to further decrease nuisance alarms. Abbreviations: *HR* = heart rate, *RR* = respiratory rate, *BP* = blood pressure, *S/D/M* = systolic, diastolic, and mean.

Table 2

Electrode Lead/Pad and Probe Changing EBP Protocol

Humidity Level and Electrode Size	Procedure
High humidity (>70%) with small electrode leads	<ul style="list-style-type: none"> ● Protective skin barrier (i.e., Duoderm) in use ● Change every third day between 2000 (8 p.m.) and 0000 (midnight) ● Replace electrode leads/pads if peeling ● Change O2 saturation probe at same time as electrode leads/pads
Low humidity with large electrode leads/pads	<ul style="list-style-type: none"> ● Change electrode lead/pad every other day between 2000 (8 p.m.) and 0000 (midnight) ● Change O2 saturation probe at same time as electrode leads/pads

The physiological monitoring protocol was developed in collaboration with a neonatal clinical nurse specialist based on ranges considered within normal limits for the neonates fitting into a given profile considering weight, oxygen status and physiological condition (PPHN or Cardiac) (Kenner, Brueggemeyer & Gunderson, 1993). The

electrode lead/pad changing protocol was also developed in collaboration with a neonatal clinical nurse specialist related to integumentary status of neonates at different weights/ages (Kenner, Brueggemeyer & Gunderson, 1993). The neonatal clinical nurse specialist referred to a foundational neonatology source, *Comprehensive Neonatal Nursing; A Physiological Perspective* (Kenner, Brueggemeyer & Gunderson, 1993). The protocols are also reflective of the AACN guidelines for alarm management (2013).

Data Analysis

Descriptive statistics including range, median and mode were done for pre and post-intervention aggregate data. The baseline frequencies for false alarms, nuisance alarms and clinically relevant alarms were summarized for each measure of respirations, blood pressure (BP), pulse, heart rate (HR)/ electrocardiogram (ECG), ventilator (vent)/RAM cannula, continuous positive airway pressure (CPAP)/RAM cannula, Nitric Oxide. A chi-square test was conducted to examine the association between monitoring type and alarm type. Assessments for measures of strong association were done. The frequency at post-intervention of each measure was analyzed using ANOVA models on the logarithmic transformed frequency with time (baseline vs Wave 2, Wave 3 and Wave 4 postintervention) for each alarm type of false alarm, nuisance alarm, or clinically relevant alarm, separately. Chi-square tests were conducted in examining the difference among monitoring type and time. In all the above analysis, a statistical significance level of 5% was used.

Project Evaluation Plan

Key information for evaluating success of the project was identification of clinically relevant and statistically significant decreases in incidence of false alarms and nuisance alarms, and indications of decreases sustained over time based upon comparison of pre-post data. As noted above, a 5% significance level was used to determine statistically significant differences. Based on conversations with RNICU nurse leaders, it was determined results of the EBP project were considered clinically relevant with at least a 10% decrease in the average number of nuisance and false alarms.

Summary

Two EBP protocol interventions were used with the intent to decrease false alarms and nuisance alarms in the RNICU. A quasi-experimental time series design was used. There were no human subjects for this project; data collection was related to alarms and the EBP protocol interventions. Project assistants were used to collect alarm and protocol data via observations in the RNICU. RNICU staff was aware that observations were being done, but they did not know what data was specifically being collected. Four waves of data collection were done; one pre-intervention and three post-intervention to determine the impact and initial sustainability of the EBP protocol interventions. Statistical analysis was done to determine if the EBP protocol interventions made statistically significant improvements in the incidence of nuisance alarms and false alarms. This information was considered in relation to the developing conceptual model for alarm fatigue and alarm safety.

Section 4: Findings, Discussion, and Implications

Summary and Evaluation of Findings

This study took place in a 35-bed, Level III regional neonatal intensive care unit. The purpose of this study was to decrease alarm fatigue and improve alarm safety in the RNICU with the use of EBP intervention protocols. The protocols used were the monitoring parameter EBP protocol and the electrode lead/pad and probe changing protocol. The specific aims or objectives of this study were as follows:

1. Determine whether the use of five sets of specific options for physiological monitoring would significantly decrease the prevalence of nuisance alarms; this is the monitoring parameter EBP protocol.
2. Determine whether the implementation of a lead changing procedure would significantly decrease the prevalence of false alarms; this is the electrode lead and probe changing EBP protocol.
3. Determine if the above interventions could be sustained.
4. Examine relationships of alarm fatigue and alarm safety related concepts.

A quantitative, time-series quasi-experimental design was used. Data were collected in four waves. Baseline data were collected in wave one prior to implementing the EBP protocols. Postimplementation data were collected in Waves 2, and 4. As discussed previously, observations were done in 15-minute increments for all occupied beds in the 35-bed unit during various times of day and night and on various days of the week. Key observation alarm data and data related to protocol adherence are included in Table 3.

Descriptive statistics showing the range, median, and mode for collected alarm data are included in Appendix G. Across the four waves of data collection, no statistically significant differences were noted between times of day ($p = .851$) or day of week ($p = .200$) related to the number of alarms.

The total number of alarms observed by project assistants during Wave 1, baseline data collection, was 420. RNICU staff were then educated on the protocols, and the protocols were implemented. In Wave 2, Wave 3, and Wave 4, there were 228, 201, and 187 alarms observed, respectively. The total number of alarms observed per wave was divided by the amount of observation time to determine an average number of alarms per hour per bed. The average number of alarms per hour per bed in Wave 1 was 22.88. This per hour per bed alarm rate for Wave 2 was 13.23, which is a 42% decrease from wave 1 ($p < .001$). After Wave 2, the Sat-Sec buffer setting was adjusted from 15 to 30. This was the only change in protocols between Wave 2 and Waves 3 and 4. The alarm rate for Wave 3 was 12.28, which is a 46% decrease from Wave 1 ($p < 0.001$). The rate for Wave 4 was 11.43 alarms per bed per hour, which is a 50% decrease from Wave 1 ($p < 0.001$).

The monitoring parameter protocol was intended to decrease the frequency of nuisance alarms. This protocol was followed 95.71% of the time during Wave 2, 85.07% of the time during Wave 3, and 98.48% of the time during Wave 4. Related to this, the numbers of nuisance alarms observed across the waves of data collection were 270 for Wave 1, 53 for Wave 2, 61 for Wave 3, and 35 for Wave 4. The numbers of nuisance alarms were also divided by the observation time to determine an average number of

nuisance alarms per hour per bed. These rates were 14.71, 3.08 (79% decrease from baseline, $p < .001$), 3.73 (74% decrease from baseline, $p < .001$) and 2.14 (85% decrease from baseline, $p < .001$) across the four waves. As expected, the average number of nuisance alarms per hour per bed does vary inversely with protocol adherence; the higher the adherence, the lower the number of nuisance alarms.

The neonatal electrode lead changing protocol was intended to decrease the frequency of false alarms. This protocol was followed 74.29% of the time during Wave 2 data collection, 76.12% of the time during Wave 3 data collection, and 70.59% of the time during Wave 4 data collection. The number of false alarms observed at base line was 68. Postimplementation of this protocol, there were 30 observed false alarms for Wave 2, 36 for Wave 3, and 26 for Wave 4. Dividing the number of observed false alarms by observation time resulted in following average number of false alarms per hour per bed rates: 3.70, 1.74 (53% decrease from baseline, $p = .009$), 2.20 (41% decrease from baseline, $p = .019$), and 1.59 (57% decrease from baseline, $p < .001$). Although there were consistent decreases in the numbers of false alarms post intervention, the number of false alarms per wave of data collection did not vary with the protocol adherence as anticipated.

Data were also collected related to clinically relevant alarms. The number of clinically relevant alarms per wave was 82 for Wave 1, 145 for Wave 2, 104 for Wave 3, and 125 for Wave 4. When these were divided by observation time, the numbers of clinically relevant alarms per hour per bed were 4.47, 8.42, 6.35, and 7.64. It is expected that the numbers of clinically relevant alarms would vary related to neonate acuity.

Table 3

Alarm Data and Protocol Adherence

	Wave 1	Wave 2	Wave 3	Wave 4
Total # of alarms observed during data collection	420	228	201	187
Avg. # of all alarms per hour per bed (Change from Wave 1)	22.88	13.23 (↓ 42%)	12.28 (↓ 46%)	11.43 (↓ 50%)
Adherence to Monitoring Parameter Protocol	n/a	95.71%	85.07%	98.48%
Total # of nuisance alarms observed during data collection	270	53	61	35
Average # of Nuisance alarms per hour per bed (Change from Wave 1)	14.71	3.08 (↓ 79%)	3.73 (↓ 74%)	2.14 (↓ 85%)
Adherence to Electrode & Probe changing Protocol	n/a	74.29%	76.12%	70.59%
Total # of false alarms observed during data collection	68	30	36	26
Average # of false alarms per hour per bed (Change from Wave 1)	3.70	1.74 (↓ 53%)	2.20 (↓ 41%)	1.59 (↓ 57%)
Total # of clinically relevant alarms observed during data collection	82	145	104	125
Average # of clinically relevant alarms per hour per bed	4.47	8.42	6.35	7.64

Discussion

Overall, the findings indicate that the EBP protocol interventions decreased nuisance and false alarms as intended, and thus support the hypotheses of the study. The neonatal electrode lead changing protocol did decrease the frequency of false alarms, and the neonatal monitoring parameter protocol outlining use of specific default monitoring parameters did decrease the frequency of nuisance alarms. The findings also show initial sustainability of the protocols. Further, the findings support the Conceptual Model for Alarm Fatigue and Alarm Safety. The interventions designed to decrease false alarms and nuisance alarms did so, thus reducing alarm workload. Additionally, the percentage of clinically relevant alarms increased post-intervention indicating likely improvement in alarm safety per the model. A visual overview of changes in alarms postintervention is provided in Figure 2.

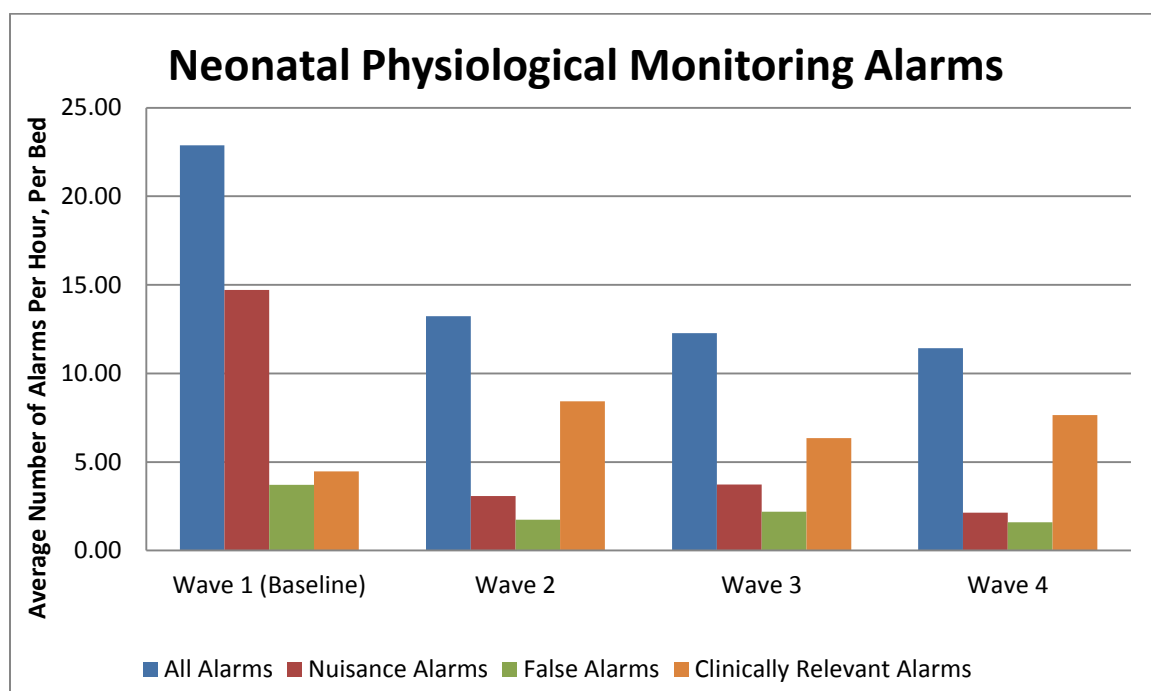


Figure 2. Neonatal physiological monitoring alarms.

Implications

The implications of this study are multifactorial. Initially, there is temptation to estimate the magnitude of this study by using the per hour, per bed rate to calculate the total numbers of alarms for the 35-bed unit over the course of 24 hours. While this would provide some very notable numbers, it would also multiply sampling errors by factors of 35 and 24. Subsequently, this was not done. Even so, decreasing the total number of alarms by 42%, 46% and 50% over Waves 2, 3, and 4 is noteworthy. These findings also provide initial indications of sustainability for the protocols and warrant further efforts be made towards broader spectrum application of the protocols.

From a policy perspective, this project impacts policy and practice at the organizational level and has meaningful implications for regulatory policy at the national level. The RNICU used in the study plans to keep both protocols in place given the improvements noted. At a higher or regulatory policy level, this study supports the importance of the NPSG by TJC: “Improve the safety of Clinical Alarm Systems” (2014). This study shows clinical alarm safety is relevant to the physiological monitoring of neonates, and that EBP protocols can significantly decrease both nuisance alarms and false alarms.

From a practice perspective, this study demonstrates how EBP strategies recommended in the physiological monitoring of adults can be applied to the physiological monitoring of neonates to decrease both nuisance and false alarms. The protocols and findings from this project could be used in other neonatal intensive care units (NICU) and in neonatal intermediate care units where physiological monitoring

may also be needed. The American Hospital Association (AHA) reports that for FY 2013, 983 hospitals operated NICUs; this is about 20-21% of hospitals in the AHA data base (AHA staff, personal communication, May 2015). There are also 714 hospitals (15% of data base) who reported neonatal intermediate care units for that same time frame. Additionally, given the international nature of alarm fatigue indicated by publications on this topic from various countries, this study could promote alarm safety in NICUs internationally.

There are also implications from this project for further study. Ideally, this project should be replicated in other NICUs. This type of scholarly project would provide additional information about the application of EBP protocols and how outcomes may or may not be similar given the size of the NICU and the type of equipment. One way this could be approached is from an epidemiological perspective.

Per Pronovost, Murphy, and Needham “the epidemiology of preventable harm is immature” (2010, p. 1463). Even so, solutions could potentially be gained from an epidemiological perspective in a much more efficient and faster manner. Contact could be made with the Vermont Oxford Network (VON) to collaborate on multi-hospital study. VON’s mission is “to improve the quality and safety of medical care for newborn infants and their families through a coordinated program of research, education, and quality improvement projects” (n.d.). In addition, per the VON website, “Vermont Oxford Network has evolved into a community of practice that includes nearly 1,000 centers around the globe that voluntarily submit data about the care and outcomes of high-risk newborn infants. The VON Databases hold critical information on more than 2

million infants, representing more than 63 million patient days” (n.d.). As such, VON could be the ideal collaborative partner for this type of research initiative. Neonatal units interested in participating would be informed of a minimum 6 month commitment to participate in the study. The goal would be to enroll at least 10 sites for participation in the study, with interest in including sites of varying sizes in both urban and rural settings. Demographic type information would be collected for each participating unit to help with study analysis. This information would include type and size of hospital (rural/urban/critical access, teaching hospital, Magnet®, bed size), type and size of unit (i.e., NICU level or neonatal intermediate care and number of beds), make and model of physiological monitoring equipment, and information on unit staff (number of FTE, education level, certification rates, years of RN experience, and years of experience on the specific unit). As indicated, testing the protocols from this epidemiological approach could provide a large amounts of information related to effectiveness of the EBP protocols in a relatively short amount of time.

From a social change perspective, this study has the potential to provide safer and more effective care for neonates and more satisfying work environments for clinicians practicing in such units, both nationally and internationally. Neonatal care environments around the world use alarm systems to provide clinically relevant data. In a safer environment, NICU nurses would have less alarm fatigue and patients would be at decreased risk of delayed or failed response to an alarm that could result in poor patient outcomes up to and including patient death.

Project Strengths and Limitations

An initial limitation for the project was the lack of a framework directly related to alarm fatigue and/or alarm safety. A strength of the project was the development of a model that was directly related to alarm fatigue and/or alarm safety. An additional strength of the study was the findings were consistent with the Conceptual Model for Alarm Fatigue and Alarm Safety; interventions to decrease nuisance and false alarms result in a higher percentage of clinically relevant alarms thus promoting alarm safety (Probst, 2014).

Another strength of the study was the selected RNICU. The unit had volume to support the study. Also as noted previously, the unit selected is known to have staff with a history of being receptive to change and efforts to improve quality of care.

A factor that could be viewed as a challenge for replication of the project is data collection. This study used observation and manual data collection. This is resource intensive. Alarm data from the monitoring equipment reports can provide some information related to total numbers of alarms and may provide some differentiation between types of alarms. If this type of report is used in combination with census and acuity data, it could provide alternative outcome measures.

Additional study in this area would be strengthened by further literature search and review to determine if more evidence becomes available related to addressing alarm fatigue and improving alarm safety in the NICU environment. Additional study in this area would help further assess the protocols and the Conceptual Module for Alarm

Fatigue and Alarm Safety (Probst, 2014). Also, with study replication, other factors that impact alarm safety may be noted.

Analysis of Self

I have been in progressive leadership positions for approximately 20 years. I am a servant and transformational leader with a flexible leadership style. As a servant leader, I am there to serve members of my team; to me this means making sure they have whatever they need to be successful in their work. Transformational leadership “is based on the concept of empowering all team members to work together to achieve a shared goal” (Zaccagnini & White, 2011, p. 251). As a transformational leader, I am there to help them evolve to the identified and desired future state. As to a flexible leadership style, I assess where the team is and provide the type of direction, guidance and support that that they need to develop as a team and be successful in meeting their goals.

I also see myself as a life-long learner. As such, I am continuously evolving as a leader, scholar, practitioner, and project developer. I also see the roles of leader, scholar, practitioner and project developer as requiring a multitude of abstract skills. I think of these abstract skills on continuum ranging from novice to expert (Benner, 1984). Given my over 20 years in nursing, with 16 of those being an advance practice nurse in progressive leadership roles, I consider myself competent to expert depending on the specifics of the situation and the work to be done. At this point I see myself as proficient related to my understanding and ability to lead EBP changes to improve alarm safety.

From another perspective, The American Association of Colleges of Nursing (AACN) in their document entitled *The Essentials of Doctoral Education for Advanced Nursing Practice* (2006) outlines eight key areas with related expectations as follows:

- I. Scientific Underpinnings for Practice
- II. Organizational and Systems Leadership for Quality Improvement and System Thinking
- III. Clinical Scholarship and Analytical Methods for Evidence-Based Practice
- IV. Information Systems/Technology and Patient Care Technology for Improvement and Transformation of Health Care
- V. Health Care Policy for Advocacy in Health Care
- VI. Interprofessional Collaboration for Improving Patient Population Health Outcomes
- VII. Clinical Prevention and Population Health for Improving the Nation's Health
- VIII. Advanced Nursing Practice

Further, AACN articulates that expectations can be delineated into two areas of foci: Advanced Practice Nursing (more direct patient focus) and Aggregate/Systems/Organization Focus (more leadership or administrative focus) (2006). My primary focus area has been Aggregate/ Systems/Organization leadership, and I have grown in this area throughout my DNP studies and related to this project.

My growth is also related to American Organization of Nurse Executives' (AONE) competencies. The Communication and Relationship-Building realm, the Knowledge of the Health Care Environment realm, and the Leadership realm of the

AONE competencies have been relevant to my DNP studies and this project work. Of particular relevance is the role of the senior nurse leader in ensuring EBP; I have demonstrated growth in this AONE competency area also throughout my DNP studies and this project work. Without skills in these areas, my project would not have come to fruition or seen completion.

As to this project and my future professional development, I see several potential opportunities. I see the potential to disseminate the findings from this project through poster presentation, podium presentation and publications. I also think there are development opportunities through additional project work in this area. It would be beneficial and rewarding to collaborate with other NICUs and explore the potential to replicate this study elsewhere.

Summary and Conclusions

This was a successful EBP project. The protocols resulted in both statistically significant and clinically relevant reductions in false and nuisance alarms thus promoting alarm safety in the neonatal intensive care environment. The findings of the study support both the hypotheses for the study and Conceptual Model for Alarm Fatigue and Alarm Safety (Probst, 2014). This study reflects the potential to create neonatal care environments, nationally and internationally, where the predominance of alarms are clinically relevant and thereby create a sense of urgency in response. Strengths and limitations of the study were discussed. Further study in the area would be beneficial to further evaluate the protocols and further assess the Conceptual Model of Alarm Fatigue

and Alarm Safety (Probst, 2014). Additionally, this project furthered my growth as a nurse leader, scholar, practitioner, and project developer.

Section 5: Scholarly Product – Sample Paper for Presentation

Introduction

Alarm fatigue is a pressing national issue that compromises patient safety (Cvach, 2012; The Joint Commission [TJC], 2013). To the degree that alarm fatigue can be prevented, alarm safety can be promoted and patients will be safer. Many types of equipment used in hospitals have alarms that are intended to ensure safer patient care. The alarm is supposed to sound when the patient is in need of clinical care and intervention. The reality is alarms are often not clinically relevant. They do not help health care workers know when care and intervention are needed. All too frequently, the alarms are false and nuisance alarms; these nonclinically relevant alarms are associated with alarm fatigue and desensitization in clinicians, which have been linked to patient harm and death (TJC, 2013).

There is increasing awareness of the potential hazards associated with alarms with research showing “. . . 72%–99% of clinical alarms are false” (American Association of Critical Care Nurses [AACN], 2013, p. 378). Some sources also report that alarms are the number one technical hazard for patients (AHC Media, 2013). Specific to the growing body of evidence and reports of patient harm and death, TJC introduced a new National Patient Safety Goal (NPSG) in July of 2014. NPSG.06.01.01 reads “Improve the safety of clinical alarm systems” (TJC, 2014).

The Problem

Alarm fatigue is a problem that creates risk and compromises patient safety. TJC now has language to address alarm safety, and the AACC recommends specific strategies

or interventions designed to reduce the prevalence of alarms that do not require clinical intervention. As indicated earlier, alarms that do not require clinical intervention are commonly referred to as false alarms and nuisance alarms. Decreasing these types of alarms can reduce the risk for or amount of alarm fatigue and subsequently decrease the risk of a serious safety event caused by or related to a failed or delayed response to a clinical alarm. This problem is relevant to hospitalized patients of all ages; however, the majority of the scholarly work done thus far has been related to adults. The focus area for this study was alarm fatigue and alarm safety as it relates to the physiological monitoring of neonates in an intensive care environment.

Purpose Statement and Project Objectives/Aims

The purpose of this study was to decrease alarm fatigue and improve alarm safety in the RNICU with the use of EBP intervention protocols.

The specific aims or objectives of this study were as follows:

1. Determine whether the use of five sets of specific options for physiological monitoring would significantly decrease the prevalence of nuisance alarms; this is the monitoring parameter EBP protocol.
2. Determine whether the implementation of a lead changing procedure would significantly decrease the prevalence of false alarms; this is the electrode lead and probe changing EBP protocol.
3. Determine if the above interventions could be sustained.
4. Examine relationships of alarm fatigue and alarm safety related concepts.

Significance/Relevance to Practice

The significance to practice is the potential to create an environment where all or most alarms are clinically relevant and thereby create a sense of urgency in response.

The significance to patient outcomes is the decreased risk of delayed or failed response to an alarm that could result in poor patient outcomes up to and including patient death.

Project Question

EBP projects often frame the question of interest in a “PICO” format where “P” is the population of interest, “I” is the intervention, “C” is the comparison of the intervention, and “O” is the outcome (Grove, Burns & Gray, 2013). The PICO question for this study reads:

Related to the physiological monitoring of neonates, can alarm management protocols designed to decrease false and nuisance alarms (as compared with no protocols) improve alarm safety via decreased alarm burden and alarm fatigue as evidenced by statistically and clinically significant reductions in false and nuisance alarms?

Hypotheses and Null Hypotheses

Hypotheses specific to the study were as follows:

- The neonatal electrode lead changing protocol will decrease the frequency of false alarms.
- The neonatal monitoring parameter protocol outlining use of specific default monitoring parameters will decrease the frequency of nuisance alarms.

Null hypotheses specific to the study were as follows:

- The neonatal lead changing protocol will not decrease the frequency of false alarms.
- The neonatal monitoring parameter protocol outlining use of specific default monitoring parameters will not decrease the frequency of nuisance alarms.

Evidence-Based Significance of the Project

Both estimates and actual data on the prevalence of alarms are featured in the literature; two specific examples of actual data are shared here. In one study of physiological alarm load in a medical-surgical setting, researchers found the following: “The average number of alarms per patient was 69.7 alarms. When this is adjusted to the duration of monitoring, an average per patient, per day rate was 95.6 alarms” (Gross, Dahl, & Nielsen, 2011, p. 29). In a study related to physiological alarms on a 15 bed medical progressive care unit, researchers found the following: “During an 18-day period, the number of alarms totaled 16,953, equating to 942 alarms per day” (Graham & Cvach, 2010, p. 32). As noted previously, TJC has regulatory language, and the AACC recommends specific strategies or interventions that can reduce the prevalence of alarms that do not require clinical intervention. As previously stated, alarms that do not require clinical intervention are commonly referred to as false alarms and nuisance alarms. Decreasing these alarms can reduce the risk or amount of alarm fatigue and subsequently decrease the risk of a serious safety event caused by or related to a failed or delayed caregiver response to a clinical alarm. Additionally, per TJC’s Sentinel Event database, “. . . there have been 98 alarm-related events between January 2009 and June 2012. Of the 98 reported events, 80 resulted in death, 13 in permanent loss of function...” (2013, p.

1). Health care views any serious safety event as one too many and advocates for proactive measures to ensure safety and prevent reoccurrence of similar events.

Definition of Terms

Multiple key terms have been introduced thus far, and some are defined here. An *alarm* is defined as “a signal (as a loud noise or flashing light) that warns or alarms” (Merriam-Webster, n.d.). A *clinical alarm* is a signal intended to provide warning in a clinical or patient care environment. A *false alarm* is defined as “an alarm that is set off needlessly; causing alarm or excitement that proves to be unfounded” (Merriam-Webster, n.d.). A *nuisance alarm* is when “monitor parameter thresholds are set too tight; true but clinically insignificant” (Cvach, 2012, p. 269). *Alarm fatigue* is “when a caregiver can become overwhelmed by a large number of clinical alarms such that alarm-related events can be missed or ignored” (Keller, 2012, p. 589). *Alarm fatigue* has also been defined as “the lack of response due to excessive numbers of alarms resulting in sensory overload and desensitization” (Cvach, 2012, p. 269).

Conceptual Model

For this scholarly project, studying alarm fatigue and alarm safety in the neonatal intensive care unit, a conceptual framework specific to alarm fatigue and alarm safety is helpful and is feasible based on knowledge of clinical practice. Not only does the development of this framework serve as a more logical and pragmatic approach to the study, it offers enhanced clarity and consistency. It does not require a crosswalk or in depth explanations as to how the alarm related concepts and study interventions fit within a current theory.

Relational statements for the model are as follows:

1. Alarm fatigue (AF) exists if and only if there is alarm burden (AB) over time.
2. Nuisance alarms (NAs) have a positive correlation with alarm burden (AB) and alarm fatigue (AF).
3. False alarms (FAs) have a positive correlation with alarm burden (AB) and alarm fatigue (AF).
4. Work capacity has a negative correlation with process/practice variations.
5. Alarm fatigue has a positive correlation with alarm risk behaviors (ARBs) (i.e., delayed response, no response, silencing alarm without checking patient, turning off monitoring equipment).
6. Alarm fatigue has a negative correlation with alarm safety (AS).
7. As the percentage of clinically relevant alarms (CRAs) increases, alarm safety (AS) increases.

Assumptions for the model include the following:

1. Alarm workload exists in a dynamic environment and is a combination of all alarms (i.e., clinically relevant alarms, nuisance alarms & false alarms).
2. Alarm burden exists and occurs when alarm workload exceeds work capacity.
3. Alarm fatigue exists and is a product of alarm burden over time; it is a subjective experience.
4. Decreasing alarm burden and alarm fatigue improves alarm safety.
5. The higher the percentage of alarms that are clinically relevant, the higher the level of alarm safety.

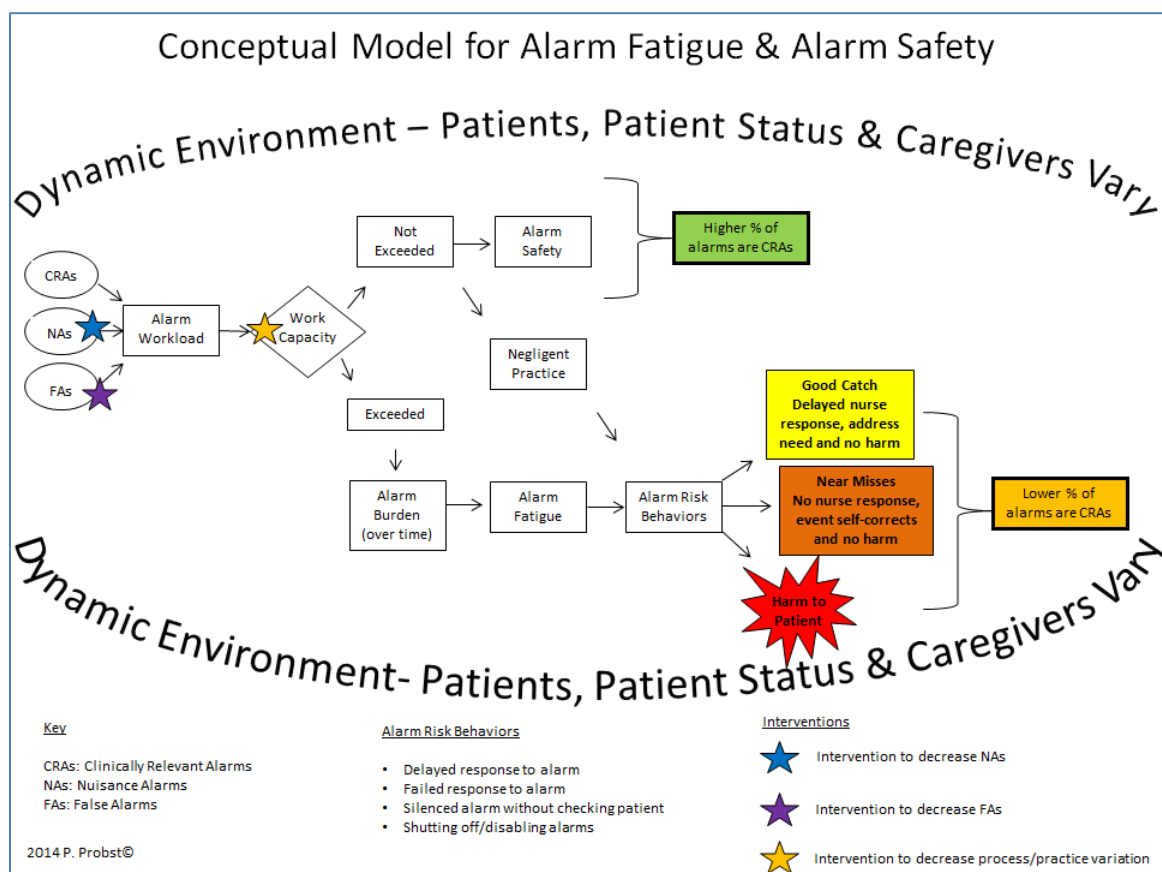


Figure 1/Slide or Handout 1. Conceptual model for alarm fatigue and alarm safety.

Per the model, alarms happen in a dynamic clinical environment where patients, patients' statuses, and caregivers such as nurses and technical support persons vary. Clinically relevant alarms, nuisance alarms and false alarms combine to create an alarm workload. If the alarm workload does not exceed the work capacity of the caregivers, alarm safety is likely. A caveat to this is that negligent practice exists when caregivers opt not to respond to alarms even though they have the ability to do so. However, if the alarm workload exceeds the work capacity of the caregivers, this creates an alarm burden which over time results in alarm fatigue. Caregivers faced with alarm fatigue are subject

to alarm risk behaviors such as delayed or failed response to alarms, silencing alarms without checking the patient, and shutting off or disabling an alarm. Alarm risk behaviors can result in different outcomes. The caregiver could eventually get to the alarm; there is a good catch and no harm to the patient. The caregiver could not get to the alarm; however, the situation corrects itself. There is a near miss, but no harm to the patient is realized. Lastly, the caregiver could not get to an alarm, a serious event happens, and there is harm to the patient. Related to this overall situation, the model indicates that alarm safety is more likely when there a high percentage of alarms that are clinically relevant. Conversely, if there is a low percentage of alarms that are clinically relevant, alarm safety is less likely.

Project Design/Methods

This was a scholarly project modifying what is known about management of physiological alarms used for adults and applying that evidence to the management of physiological alarms for neonates. A quantitative, time series quasi-experimental design was employed to facilitate study aims. The two independent variables in this study included a) intervention of implementing the monitoring parameter EBP protocol and b) intervention of implementing an electrode lead and probe changing EBP protocol. The following dependent variables were measured: a) number of nuisance alarms, and b) number of false alarms.

Setting and Sampling

An RNICU was selected for several reasons. As this is a critical care unit, physiological monitors with alarms are routinely used. The average daily census ensured

availability of patients undergoing monitoring for alarm data collection purposes. Given the physical set-up of the unit, monitoring equipment could easily be observed by project assistants for data collection purposes. The staff has a history of being engaged in efforts to improve quality of care, and there is staffing stability for the unit; both of these factors were beneficial when considering the introduction of the EBP protocol interventions.

Sampling of alarm frequencies and types was done. Related to the sampling of alarms, each of the 35 occupied beds within the RNICU was observed by the project assistants in 15-minute increments to collect data on alarm frequency and types. These 15-minute observations were done during blocks of time at different times of the day and night as well as on different days of the week and weekend; observation data was used to calculate averages. Block times were up to 5 hours to allow for 16 beds to be observed and transitions between observations. For the purposes of this study, the bed assignment numbers used for admission and electronic medical record purposes were not referenced in the data collections as this could be viewed as identifying data. Beds were assigned numbers 40-74 for the purposes of tracking observation of all 35 beds. There were a total of 4 waves of data collection. Wave 1 was prior to implementation of the intervention. Wave 2 was two weeks after initial interventions, Wave 3 was two weeks after the second interventions (change in monitoring protocol related to saturation-seconds), and Wave 4 was four weeks after second interventions.

Project Evaluation Plan

Key information for evaluating success of the project was identification of statistically significant decreases in incidence of false alarms and nuisance alarms, and

indications of decreases sustained over time based upon comparison of pre-post data. As noted above, a 5% significance level was used to determine statistically significant differences.

Findings and Discussion

Overall, the findings indicate that the EBP protocol interventions did what they were intended to do, and thus support the hypotheses of the study. The neonatal electrode lead changing protocol decreased the frequency of false alarms and the neonatal monitoring parameter protocol outlining use of specific default monitoring parameters decreased the frequency of nuisance alarms.

The findings also support the Conceptual Model for Alarm Fatigue and Alarm Safety. The interventions designed to decrease false alarms and nuisance alarms did so, thus reducing alarm workload. Additionally, the percentage of clinical alarms increased post-intervention indicating likely improvement in alarm safety per the model.

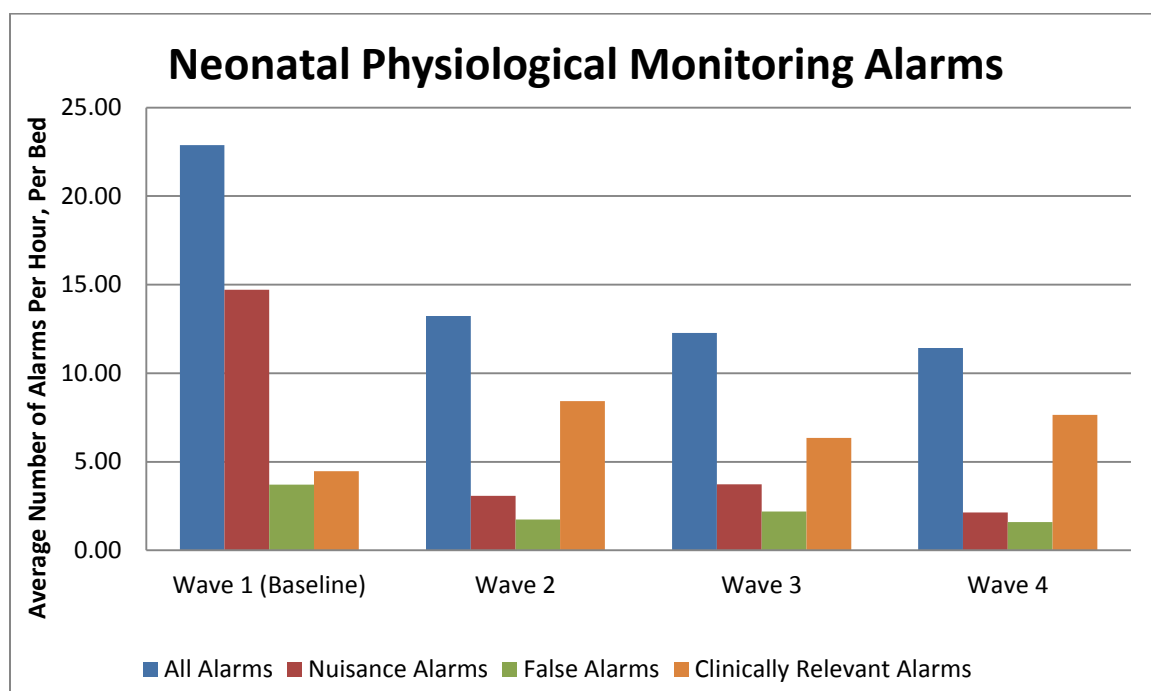


Figure 2/Slide or Handout 2. Neonatal physiological monitoring alarms.

Implications

The implications of this study are multifactorial. Initially, there is temptation to estimate the magnitude of this study by using the per hour, per bed rate to calculate the total numbers of alarms for the 35-bed unit over the course of 24 hours. While this would provide some very notable numbers, it would also multiply sampling errors by factors of 35 and 24. Subsequently, this was not done. Even so, decreasing the total number of alarms by 42%, 46% and 50% over Waves 2, 3, and 4 is remarkable. These findings also provide initial indications of sustainability for the protocols and warrant further efforts be made towards broader spectrum application of the protocols.

From a policy perspective, this project impacts policy and practice at the organizational level and is related to regulatory policy at the national level. The RNICU used in the study plans to keep both protocols in place given the improvements noted. At

a higher or regulatory policy level, this study supports the importance of TJC NPSG to “Improve the safety of Clinical Alarm System” (2014). This study shows clinical alarm safety is relevant to the physiological monitoring of neonates, and that EBP protocols can significantly decrease both nuisance alarms and false alarms.

From a practice perspective, this study demonstrates how EBP strategies recommended in the physiological monitoring of adults can be applied to the physiological monitoring of neonates to decrease both nuisance and false alarms. The protocols and findings from this project could be used in other neonatal intensive care units (NICU) and in neonatal intermediate care units where physiological monitoring may also be needed. The American Hospital Association (AHA) reports that for FY 2013, 983 hospitals operated NICUs; this is about 20-21% of hospitals in the AHA data base (AHA staff, personal communication, May 2015). There are also 714 hospitals (15% of data base) who reported neonatal intermediate care units for that same time frame. Additionally, given the international nature of alarm fatigue indicated by publications on this topic from various countries, this study could promote alarm safety in NICUs internationally.

There are also implications from this project for further study. Ideally, this project should be replicated in other NICUs. This type of study would provide additional information about the application of EBP protocols and how outcomes may or may not be similar given the size of the NICU and the type of equipment. One way this could be approached is from an epidemiological perspective.

Per Pronovost, Murphy, and Needham “the epidemiology of preventable harm is immature” (2010, p. 1463). Even so, solutions could potentially be gained from an epidemiological perspective in a much more efficient and faster manner. Contact could be made with the Vermont Oxford Network (VON) to collaborate on multi-hospital study. VON’s mission is “to improve the quality and safety of medical care for newborn infants and their families through a coordinated program of research, education, and quality improvement projects” (n.d.). Additionally, per the VON website, “Vermont Oxford Network has evolved into a community of practice that includes nearly 1,000 centers around the globe that voluntarily submit data about the care and outcomes of high-risk newborn infants. The VON Databases hold critical information on more than 2 million infants, representing more than 63 million patient days” (n.d.). As such, VON could be the ideal collaborative partner for this type of research initiative. Neonatal units interested in participating would be informed of a minimum 6 month commitment to participate in the study. The goal would be to enroll at least 10 sites for participation in the study, with interest in including sites of varying sizes in both urban and rural settings. Demographic type information would be collected for each participating unit to help with study analysis. This information would include type and size of hospital (rural/urban/critical access, teaching hospital, Magnet®, bed size), type and size of unit (i.e. NICU level or neonatal intermediate care and number of beds), make and model of physiological monitoring equipment, and information on unit staff (number of FTE, education level, certification rates, years of RN experience, and years of experience on the specific unit). As indicated, testing the protocols from this epidemiological approach

could provide a large amounts of information related to effectiveness of the EBP protocols in a relatively short amount of time.

From a social change perspective, this study has the potential to provide safer and more effective care for neonates and more satisfying work environments for clinicians practicing in such units, both nationally and internationally. Neonatal care environments around the world use alarm systems to provide clinically relevant data. In a safer environment, NICU nurses would have less alarm fatigue and patients would be at decreased risk of delayed or failed response to an alarm that could result in poor patient outcomes up to and including patient death.

Summary and Conclusions

Overall, this was a beneficial EBP project. The selected RNICU was engaged in the project as evidenced by high levels of adherence with the project protocols. The protocols resulted in both statistically and clinically significant reductions in false and nuisance alarms thus promoting alarm safety in the neonatal intensive care environment. The findings of the study support both the hypotheses for the study and Conceptual Model for Alarm Fatigue and Alarm Safety (Probst, 2014). The implication of this study is the potential to create neonatal care environments across the world where all or most alarms are clinically relevant and thereby create a sense of urgency in response. Strengths and limitations of the study were discussed. Further study in the area would be beneficial to further test the protocols and further assess the Conceptual Model of Alarm Fatigue and Alarm Safety (Probst, 2014).

References

- AHC Media, LCC. (2013). Alarms #1 tech risk despite focus, according to ECRI. *Hospital Peer Review*. Retrieved from <http://www.ahcpub.com>
- American Association of Colleges of Nursing (AACN). (2006). *Essentials of doctoral education for advanced nursing practice*. Washington, DC: American Association of Colleges of Nursing (AACN). Retrieved from <http://www.aacn.nche.edu/publications/position/DNPEssentials.pdf>
- American Association of Critical Care Nurses. (2013, August). *Practice alert: Alarm management*. Retrieved from <http://www.aacn.org>
- American Organization of Nurse Executives (AONE). (2011). *The AONE nurse executive competencies*. Chicago, IL: American Organization of Nurse Executives. Retrieved from www.aone@aha.org
- Armola, R., Bourgault, A., Halm, M., Board, R., Bucher, L., Harrington, L., & ... Medina, J. (2009). AACN levels of evidence: What's new? *Critical Care Nurse*, 29(4), 70–73. doi: 10.4037/ccn2009969.
- Bellomo, R., Ackerman, M., Bailey, M., Beale, R., Clancy, G., Danesh, V., ... Tangkau, P. (2012). A controlled trial of electronic automated advisory vital signs monitoring in general hospital wards. *Critical Care Medicine*, 40(8), 2349-2361.
- Benner, P. (1984). *From novice to expert; Excellence and power in clinical nursing practice*. Menlo Park, CA: Addison-Wesley.
- Borowski, M., Gorges, M., Fried, R., Such, O., Wrede, C., & Imhoff, M. (2011). Medical device alarms. *Biomed Tech* 2011, 56, 73-83. doi: 10.1515/BMT.2011.005

- Cvach, M. (2012). Monitor alarm fatigue: An integrative review. *Biomedical Instrumentation & Technology*, 46(4), 268-277.
- Cvach, M., Biggs, M., Rothwell, K., & Charles-Hudson, C. (2013). Daily electrode change and effect on cardiac monitor alarms; An evidence-based practice approach. *Journal of Nursing Care Quality*, 28(3), 265-271.
doi:10.1097/NCQ.0b013e31827993bc
- Cvach, M., Frank, R., Doyle, P., & Stevens, Z. (2013). Use of pagers with an alarm escalation system to reduce cardiac monitor alarm signals. *Journal of Nursing Care Quality*, 29(1), 9-18. Published ahead of print doi:
10.1097/NCQ.0b013e3182a61887
- Edworthy, J. (2013). Medical audible alarms: A review. *Journal of American Medical Informatics Association*, 20, 584-589. doi: 10.1136/amiajnl-2012-001061
- Graham, K. C., & Cvach, M. (2010). Monitor alarm fatigue: Standardizing use of physiological monitors and decreasing nuisance alarms. *American Journal of Critical Care*, 19, 28-34. doi: 10.4037/ajcc2010651
- Gross, B., Dahl, D., & Nielsen, L. (2011). Physiologic monitoring alarm load on medical/surgical floors of a community hospital. *Horizons*, 2, 29-36.
- Grove, S., Burns, N., & Gray, J. (2013). *The practice of nursing research: Appraisal, synthesis, and generation of evidence* (7th ed.). St. Louis, MO: Saunders Elsevier.
- Henneman, E., Gawlinski, A., & Giuliano, K. (2012). Surveillance: A strategy for improving patient safety in acute and critical care units. *Critical Care Nurse*, 32(2), 9-18. doi: 10.4037/ccn2012166.

- Keller, J. (2012). Clinical alarm hazards: A “top ten” health technology safety concern. *Journal of Electrocardiology*, 45, 588-591.
- Kenner, C., Brueggemeyer, A., & Gunderson, L. (1993). *Comprehensive neonatal nursing; A physiological perspective*. Philadelphia, PA: W. B. Saunders Company.
- Kolcaba, K. (2003). *Comfort theory and practice; A vision for holistic health care and research*. New York, NY: Springer Publishing Company.
- Konkani, A., Oakley, B. , & Bauld, T. (2012). Reducing hospital noise: A review of medical device alarm management. *Biomedical Instrumentation & Technology*, 46(4), 478-487.
- Lenz, E.R., Pugh, L.C., Milligan, R.A., Gift, A., & Suppe, F. (1997). The middle-range theory of unpleasant symptoms: An update. *Advances in Nursing Science*, 19, 14-27.
- McEwen, M., & Wills, E.M. (2011). *Theoretical basis for nursing*. Philadelphia, PA: Lippincott Williams & Wilkins.
- Melnyk, B.M. & Fineout-Overholt, E. (2011). *Evidence-based practice in nursing and healthcare: A guide to best practice*. Philadelphia, PA: Lippincott, Williams & Wilkins.
- Merriam-Webster (n.d.). *On-line Dictionary*. Retrieved from <http://www.merriam-webster.com/dictionary>
- Probst, P. (2014). *Conceptual model for alarm fatigue and alarm safety*. Unpublished work.

Prochaska, J.O. & Velicer, W.F. (1997). The transtheoretical model of health behavior change. *American Journal of Health Promotion, 12*, 38-48.

Pronovost, P. J., Murphy, D. J., & Needham D. M. (2010). The science of translating research into practice in intensive care. *American Journal of Respiratory and Critical Care Medicine, 182*(12), 1463–1464.

The Joint Commission. (2013, April). *Sentinel event alert: Medical device alarm safety in hospitals*. Retrieved from <http://www.jointcommission.org>

The Joint Commission (2014). National Patient Safety Goals. *On-line Manual for Hospitals* (August ed.). Retrieved from [https://e-
dition.jcrinc.com/MainContent.aspx](https://e-
dition.jcrinc.com/MainContent.aspx)

Vermont Oxford Network (n.d.). Retrieved from <https://public.vtoxford.org/about-us/>

Zaccagnini, M. E., & White, K. W. (2011). *The doctor of nursing practice essentials: A new model for advanced practice nursing*. (Laureate Education, Inc., custom ed.). Sudbury, MA: Jones & Bartlett Publishers.

Appendix A: Alarm Definitions for Conceptual Model

Term	Conceptual Definition*	Operational Definition
Alarm	Sound, light, and/or vibration that alerts, gives notice; i.e. fire alarm, telephone sound or vibration, pager sound or vibration	n/a
Clinical Alarm	An alarm in the clinical or patient care setting; i.e. IV pump alarm, feeding pump alarm, patient controlled analgesia alarm, fall sensor, physiological alarms such as vital sign monitor alarm or pulse oximetry monitor alarm	n/a
Physiological Alarm	An alarm associated with a physiologic measure such as temperature, heart rate, respiratory rate, oxygen saturation (pulse oximetry), nitric oxide or a physiologic function such as electrocardiography (ECG)/telemetry or ventilator	n/a
Clinically Relevant Alarm	An alarm that sounds related to a clinical parameter that is acted upon and requires a clinical intervention; i.e. administration of medication, change in oxygen therapy, therapeutic repositioning, suctioning of airway, adjustment in ventilator settings These types of alarms can also have different levels of severity such as a warning alarm that indicates a moderate level of abnormality and moderated level of intervention is needed and a critical warning alarm that indicates a life threatening situation requiring significant intervention up to and including resuscitation	Objective: observation of alarm related to clinical parameter that is clinically relevant; attention to patient is priority and care is provided to the patient
Nuisance Alarm	An alarm that sounds related to a clinical parameter, but no patient care action is needed or taken; i.e. parameter is too general for a specific patient	Objective: observation of alarm related to clinical parameter that is not clinically relevant; person tends to equipment, not patient
False Alarm	Alarm sounds unrelated to a clinical parameter but because of incomplete input/information; i.e. because of a loose lead or connection, poor lead placement, patient movement, equipment issue	Objective: observation of alarm unrelated to clinical parameter; person tends to equipment, not patient
Alarm Workload	Work needed to attend to alarms; consists of clinically relevant alarms, nuisance alarms and false alarms; workload may be distributed across numerous persons	Objective: total number of alarms in a given area over a given amount of time

Alarm Burden	Related to alarm workload; alarm burden exists when alarm workload exceeds work capacity (ability to attend to alarms)	Subjective: self-report measured through survey tool (not a part of project, but is an option) Objective: observations of delayed or failed response to alarms (not part of project, but this is an option)
Alarm Fatigue	A subjective experience that is the product of alarm burden over time; person experiencing alarm fatigue often has experience with majority of alarms in work environment being false alarms or nuisance alarms; leads to unsafe responses to alarms such as delayed response, failed response, silencing of alarm, or turning off monitoring equipment Synonymous term: desensitization to alarms	Subjective: self-report measured through survey tool (not a part of project, but is an option) Objective: observation of alarm risk behaviors (not a part of project, but is an option)
Alarm Risk Behaviors	Delayed response to an alarm, failed response to an alarm, silencing of alarm without checking the patient, turning off monitoring equipment	Subjective: self-report measured through survey tool (not a part of project, but is an option) Objective: observations of delayed or failed response to alarms; observation of alarm being silenced or turned off (not part of project, but this is an option)
Alarm Safety	Exists when a high percentage of alarms in the environment are clinically relevant; alarm burden/alarm fatigue are low or do not exist; low or no incidence of patient harm or death related to alarms	Subjective: person's perception of alarm safety as measured through survey tool (not a part of project, but is an option) Objective 1: related to % of alarms in the environment that are clinically relevant; the higher the %, the greater the safety Objective 2: low or no incidence of patient harm or death associated with clinical alarms

*Theorist's Definition: "A conceptual definition provides the theoretical meaning of a concept or variable and is derived from a theorist's definition of that concept" (Grove, Burns & Gray, 2011, p. 155).

Source: P. Probst, 2014.

Appendix B: Summary of Analyzed Articles

Summary Table of Analyzed Articles						
Citation*	Conceptual Framework/Theory	Main finding	Research method	Strengths of study	Weaknesses	Level of Evidence**
AACN, 2013	None	Practice Recommendations for alarm management	Clinical Practice Guidelines based on literature review	Uses AACN evidence guidelines	Does not speak specifically to application of EBP to neonates	Varies by recommendation
Cvach, 2012	The John Hopkins Nursing EBP Model (Nurse study)	5 themes in the research evidence; 2 in the non-research evidence; provides overview of areas for future research	Integrative review	Uses the John Hopkins Nursing EBP Model as a framework; describes literature search in details; organizes information found into themes	Does not offer definitions for all key terms/concepts	5/C
Konkani, Oakley, Bauld, 2012	None (Non-nurse study)	Organization of literature into 4 themes	Integrative review	Implications for alarm protocols, individual alarm settings, future research	No theoretical or conceptual framework	5/C
Gross, Dahl, Nielsen, 2011	None (Non-nurse study)	Compared critical care alarm parameters for use on Med-Surg floor; found that critical care parameters are too sensitive for med-surg unit; identified improvements for alarms settings	Observational, retrospective evaluation of alarm frequency	Sample size of 4104 patients	No theoretical or conceptual framework	6/C
Graham & Cvach, 2010	(Nurse Study)	Clinical monitor alarms	Small tests of change for quality	Clinically relevant reduction in alarms	No theoretical or conceptual framework; study	6/C

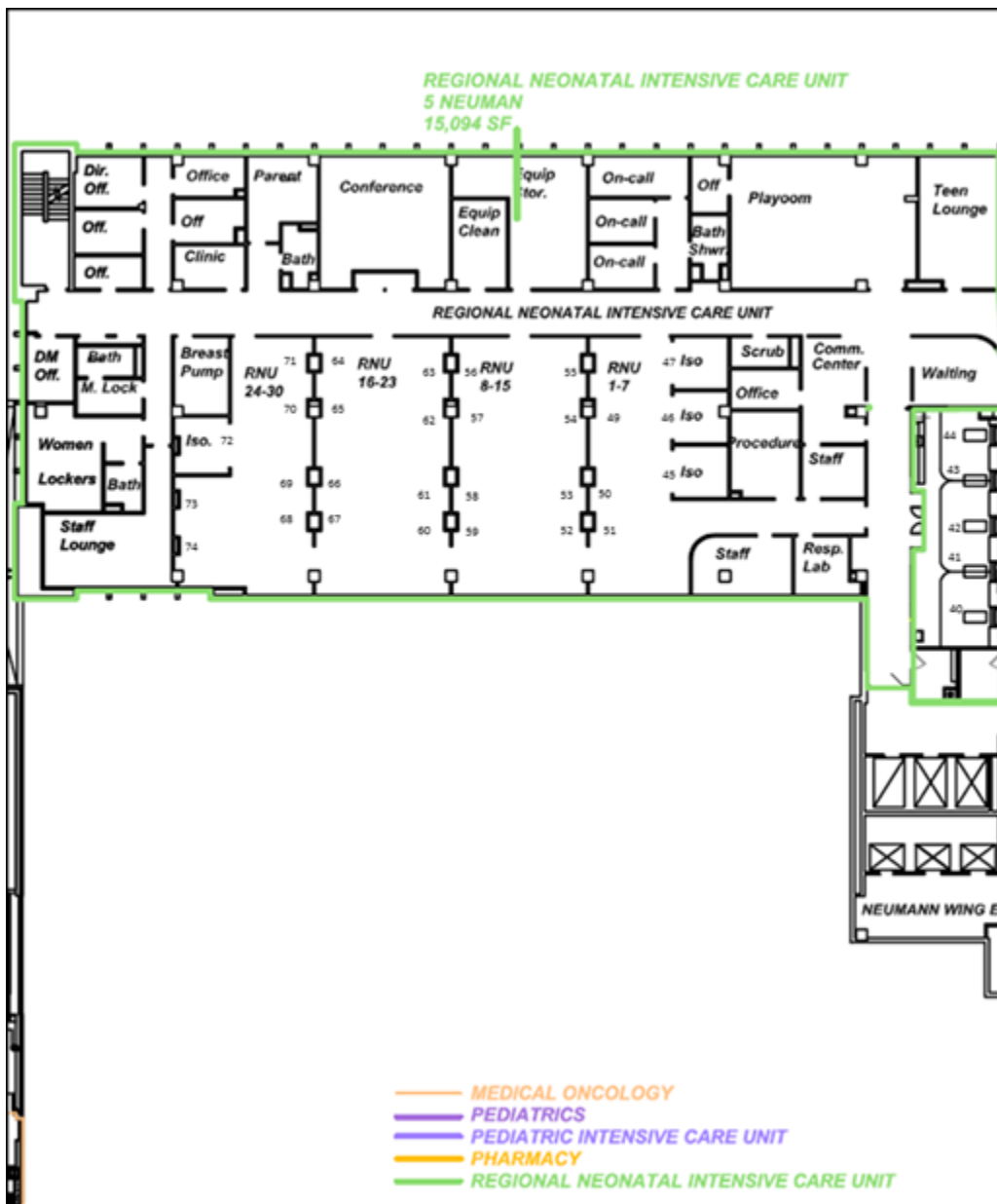
		reduced by 43% through adjustments to default settings, individualizing alarm parameters, implementing monitoring policy	improvement		limited to 1 unit	
Cvach, Biggs, Rothwell & Charles-Hudson, 2013	Not specifically stated; did use John Hopkins evidence assessment tools (Nurse Study)	Avg. alarm per bed per day decreased by 46% related to implementation of a daily electrode change protocol	Literature review and QI rapid change pilot study	Description of lit review and summary of findings that led to QI pilot study; clinically relevant reduction in alarms	Pilot study; multiple test variables in the intervention—unable to determine specific effect of each test intervention; no theoretical or conceptual framework	6/C
Henneman, Gawlinski & Giuliano, 2012	Adapted Eindhoven Model of error recovery (Nurse Study)	More than monitoring is needed; the role of surveillance in improving patient safety	Descriptive/ case study as exemplar	Delineates the importance of surveillance which is more than monitoring; identifies areas for further research	Descriptive in nature; one case study; recommendations with limited evidence to support	6-7/E
Borowski, M. et al, 2011	None (Non-nurse study)	Made the case for too many alarms and too few alarms; discussed clinical relevance of alarms, alarm fatigue and alarm related workload	Based on a position paper that includes summary of expert opinions and review of 9 studies addressing true positive alarms and false positive alarms	Good comparison of studies done related to true positive alarms and false positive alarms; gives recommendations for further research; German author—demonstrates alarm issues are international	Literature review strategy not outlined; no theoretical or conceptual framework	7/E
Edworthy, J., 2012	None (Non-nurse study)	Summary of research that is applicable to the design of auditory alarms in the medical context	Literature Review	Literature search strategy outlined; discusses “alarm philosophy”—thinking of alarms as a whole; offers recommendations; 80 references	For purpose of translation study, this is more technical than clinical; diagram/model/ concept map would be helpful related to discussion on	5/C

					alarm philosophy	
Cvach, M., Frank, R., Doyle, P., & Stevens, Z., 2013	Alarm escalation algorithm (Nurse study)	Algorithm and pagers improved response time and decreased alarm fatigue; also decreased noise at patient bedside	QI methodology to test intervention	Included a review of the literature and good detail on methods and innovation	Limited generalizability given QI approach; limited n related to nurse respondents on survey	6/C
Harris, R., Manavizadeh, J., McPherson, D., & Smith, L., 2011	None (Nurse study)	Focus on cardiac alarms; burst page alarm reduced delays in response time and saw decrease in burst alarms over time	QI methodology	Included review of the evidence; identified areas for further work	Limited generalizability given QI approach; no theoretical or conceptual framework	6/C

*See reference page for full reference information

**Number is level according to Melnyk & Fineout-Overholt Levels of Evidence (2011); letter is according to AACN's Levels of Evidence (2009)

Appendix C: Room Numbering for Data Collection



Appendix D: Project Assistant Orientation

Objectives:

1. Project Assistants (Pas) will be oriented to the layout of the RNICU
2. PAs will be able to identify the type of respiratory support and physiological monitoring that is utilized in the RNICU and document it on the data collection tool.
3. PAs will be able to identify the type of alarm sounds they will hear for each of the parameters being measured.
4. PAs will be able to state the difference between false, nuisance, and clinically relevant alarms and accurately identify these types of alarms.
5. PAs will be able to identify and accurately document if there was a nurse intervention for equipment, a nurse intervention for the patient or a nurse intervention for both.
6. PAs will demonstrate inter rater reliability through a process of comparing their data collection to an RNICU nurse collecting data simultaneously.

Orientation Plan

- Orientation to the layout of the RNICU and bed numbers to be utilized for the study.
- Orientation to the types of physiological monitoring equipment used in the RNICU and how to identify equipment in use. Equipment to be covered includes:
 - GE Monitors
 - Servo Ventilators
 - SiPAP/CPAP
 - RAM Cannulas
 - Nitric Oxide
 - Giraffe Isolettes
- Show video teaching the alarm sounds that are heard in the RNICU and how to interpret them as false, nuisance or clinically relevant.
- Orientation to the Physiological Alarm Observation Data Collection Tool
 - How to document each alarm and type of alarm
 - How to code each alarm event

- Importance of documentation of notes/comments
- PAs will practice data collection simultaneously with each other and the instructor
- Results will be compared and variations discussed
- PAs will perform data collection for competency evaluation
- PAs will be orientated to data entry

Appendix E: Alarm Observation Data Collection Sheet – Preintervention

Alarm Observation Data Collection					
Observer: _____ Date: _____ Bed #: _____ Start Time: _____ Stop Time: _____ (use military time)					
Type of Monitoring (Check all that apply)	Total Number of Alarms	Code each alarm event as follows:			Notes/Comments
		False Alarm*	Nuisance Alarm**	Clinically Relevant Alarm***	
<input type="checkbox"/> Respirations					
<input type="checkbox"/> BP					
<input type="checkbox"/> Pulse Ox/O2 Sat					
<input type="checkbox"/> HR/ECG					
<input type="checkbox"/> Vent/RAM					
<input type="checkbox"/> CPAP/RAM					
<input type="checkbox"/> Nitric Oxide					
TOTALS					

*False Alarm: alarm sounds unrelated to clinical parameter (i.e. loose lead, patient movement, equipment issue)

**Nuisance Alarm: alarm sounds related to clinical parameter, but no action needed or taken for patient (i.e. parameter too general for specific patient)

***Clinically Relevant Alarm: alarm sounds related to a clinical parameter that is acted upon/requires clinical interventions (i.e. meds, change in therapy or position, suctioning)

Appendix F: Alarm Observation Data Collection Sheet – Postintervention

Alarm Observation Data Collection					
Observer: _____		Date: _____		Bed #: _____	
		Start Time: _____		Stop Time: _____ (use military time)	
Type of Monitoring (Check all that apply)	Total Number of Alarms	Code each alarm event as follows:			Lead Changing Protocol Followed: Yes <input type="checkbox"/> No <input type="checkbox"/> Monitoring Parameter Protocol Followed: Yes <input type="checkbox"/> No <input type="checkbox"/> Notes/Comments
		False Alarm*	Nuisance Alarm**	Clinically Relevant Alarm***	
<input type="checkbox"/> Respirations					
<input type="checkbox"/> BP					
<input type="checkbox"/> Pulse Ox/O2 Sat					
<input type="checkbox"/> HR/ECG					
<input type="checkbox"/> Vent/RAM					
<input type="checkbox"/> CPAP/RAM					
<input type="checkbox"/> Nitric Oxide					
TOTALS					

*False Alarm: alarm sounds unrelated to clinical parameter (i.e. loose lead, patient movement, equipment issue)

**Nuisance Alarm: alarm sounds related to clinical parameter, but no action needed or taken for patient (i.e. parameter too general for specific patient)

***Clinically Relevant Alarm: alarm sounds related to a clinical parameter that is acted upon/requires clinical interventions (i.e. meds, change in therapy or position, suctioning)

Appendix G: Range, Median, and Mode for Alarm Observation Data

	For Alarm Observation Data Collected	Wave 1	Wave 2	Wave 3	Wave 4
All Alarms	Range	0–21	02–1	0–13	0–23
	Median	4.5	2	1	1
	Mode	0	0	0	0
False Alarms	Range	0–12	0–6	07–	05–
	Median	0	0	0	0
	Mode	0	0	0	0
Nuisance Alarms	Range	02–1	0–14	0–13	01–0
	Median	1.5	0	0	0
	Mode	0	0	0	0
Clinically Relevant Alarms	Range	0–9	0–21	0–13	0–23
	Median	0	0.5	0	0
	Mode	0	0	0	0