Improving Alarm Safety in the Regional Neonatal Intensive Care Unit

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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 a developing 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. This study also piloted a survey tool designed to assess nurse understanding of alarm related terms and nurse perceptions of clinical alarms and alarm fatigue. Additionally, relationships of alarm fatigue and alarm safety related concepts were examined. A quantitative, time series quasi-experimental design was used with 4 waves of data collection (one baseline and three post intervention). The alarm observation 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. Alarm survey data showed that RNs perceived higher levels of alarm burden and alarm fatigue when caring for patients with higher acuity levels ($p < 0.0001$ for burden; $p < 0.0001$ for fatigue). There were 3 sub-scales in the survey: 1) RN Knowledge scale, 2)
Alarm Risk Behaviors scale, and 3) Alarm Fatigue scale. Of primary interest were the Alarm Fatigue scale and the Alarm Risk Behavior scale. Over the 4 waves of data collection with the majority of respondents from RNICU, the average Alarm Fatigue Scale score decreased from 6.25 to 4.89. Additionally, the Alarm Fatigue Scale demonstrated strong internal consistency as Cronbach α ranged from 0.845 to 0.981. The average Alarm Risk Behavior Scale scores also declined from wave 1 to wave 4. Excluding wave 2, the scale demonstrated good internal consistency as Cronbach α ranged from 0.727 to 0.930. 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.
Acknowledgments

This translation research project was funded by the Michigan State University and Sparrow Center for Innovation and Research (CFIR). The project team appreciates CFIR’s support of this work.
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Section 1: Overview of the Project

Introduction

Alarm fatigue is a pressing national issue that compromises patient safety (Cvach, 2012; The Joint Commission [TJC], 2017). 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). In 2013 ECRI Institute reported that alarms are the number one technical hazard for patients (AHC Media). 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). Despite recognition of the need for alarm safety, as of 2016 ERI Institute ranked alarms as the second top technology hazard (AHC Media).
**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 and piloting a survey instrument.

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. Pilot a survey tool designed to assess nurse understanding of alarm related terms and nurse perceptions on clinical alarms and alarm fatigue.

5. 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.

Furthermore, while a survey has been conducted to assess clinician perceptions related to the effectiveness of clinical alarms, a tool to measure perceptions of alarm fatigue was not found (Korniewicz, Clark, & David, 2008). The significance to practice related to the survey component of the study is the potential to create an easy-to-use and cost-effective method for evaluating alarm fatigue and the impact of interventions designed to decrease alarm fatigue or improve alarm safety.

**Research Project Questions**

The protocols for this translation research project were evidence-based practices. As such, one of the project questions was framed in “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 questions 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?

Other project questions were addressed with the survey tool and included the following:

- Do nurse perceptions of alarm fatigue change related to changes in false alarms and nuisance alarms?
- Do nurses perceive different levels of alarm fatigue related to the acuity of their patients?
- Do nurses perceive different levels of alarm fatigue or demonstrate different alarm related behaviors related to variables such as years of experience, level of education and specialty certification?

**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.
- Changes in false alarms and nuisance alarm frequencies will impact nurse perceptions of alarm fatigue.

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.

● Changes in false alarms and nuisance alarm frequencies will not impact nurse perceptions of alarm fatigue.

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 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 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 study. 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 (2009) 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 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 RNICU, 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 Study**

A key source of evidence that supports the basis of the interventions for this translation research study 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 translation research 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 an existing 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 an IRB approved translation research project using what is known about the management of physiological alarms used for adults and applying that evidence to managing physiological alarms for neonates. Additionally, a survey instrument was concurrently piloted. 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, (b) number of false alarms and (c) nurse perceptions of clinical alarms and alarm fatigue.

Human Subjects

Registered Nurses (RNs) were the human subjects of this study as they completed the survey instrument. Neonates were not human subjects related to the EBP protocols as 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

The setting was a 600+ bed Magnet® hospital in Michigan. The 35 bed Level III 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 research 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 and related to the collection of survey data.

Given the aims of the study, there are two sampling strategies: 1) sampling of alarm frequencies and types and 2) sampling of nurses for assessing perceptions on clinical alarms and alarm fatigue. Related to the sampling of alarms, each of the 35 occupied beds within the RNICU was observed by the research 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 intervention (change in monitoring protocol related to saturation-seconds), and Wave 4: 4 weeks after second interventions. Related to the sampling for completion of the survey tool, all RNICUs RNs were invited to
complete the survey pre-interventions and 2 weeks post each intervention and 4 weeks post final intervention. Additionally, critical care RNs, medical-surgical RNs, pediatric RNs and step-down RNs were also invited to complete the survey during the same weeks that the RNICU RNs were asked to complete the survey.

**Data Collection**

Two part-time research assistants were recruited for alarm observation data collection, alarm observation and survey data entry, and other assistive support for the study. Two part-time assistants also allowed flexible scheduling to meet alarm observation 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 alarm observation 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 research 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 research assistant demonstrated competence in alarm observation data collection as evidenced by correct identification of physiological alarm type and category.
The other data collection tool is the RN Survey. Participants were invited to complete this at four points during the study as described above. There are two versions of this tool, the initial version (Appendix G) and the subsequent version. The initial version includes the collection of the demographic information; the subsequent version does not include all of the demographic information to make completion quicker/easier on the subsequent assessments. Samples of both version of the RN Survey tool were included with materials submitted to Sparrow IRB.

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 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 (Table 2). 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*

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

*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**

<table>
<thead>
<tr>
<th>Humidity Level and Electrode Size</th>
<th>Procedure</th>
</tr>
</thead>
</table>
| High humidity (>70%) with small electrode leads | - 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 | - 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**

Data analysis was planned and completed by the project statistician. Details are included below. Evaluation of results was done collaboratively to ensure accuracy and appropriate interpretation of relevance to nursing clinical practice.

**Alarm Observation Data**

Descriptive statistics including range, median and mode were done for pre and post-intervention aggregate alarm observation 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.

**Alarm Survey Data**

A baseline survey data factor analysis was conducted on the nurse perception (alarm terms and patient care) data, aiming to summarize the large number of measures of the nurse perception on alarms and patient care with a small number of important factors that help to accurately define the nurse perception on alarms and patient care. The factor analysis was conducted on the 15 measures (1-15) in part 1 with the coding scheme as 1 for strongly agree, 0 for unsure and -1 for disagree. The factor analysis was also conducted on the 8 measures (16-23) with default coding for each measure. Frequency analysis was conducted for the nurse alarm level measures (24-26) and response level measures (27-30). Demographics data of the nurses was also evaluated using descriptive statistics.

Post-intervention nurse perception data at 2 weeks, 4 weeks, and 6 weeks post-intervention was analyzed focusing the factors determined in the baseline analysis using linear regression model on the individual’s loading score of the factors. The linear regression model was applied to the logarithmic transformed individual nurse loading score with covariates including the nurse alarm levels (measures 24-26) and demographic variables (32, 40), or summary statistics of these variables, separately for 2 weeks, 4 weeks and 6 weeks post-intervention data. Each frequency level was analyzed similarly using the linear model with logarithmic transformation. Validity and reliability of items were evaluated.
**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 project were considered clinically relevant with at least a 10% decrease in the average number of nuisance and false alarms. Related to the pilot of the survey tool, the key information for determining success with this study aim was identification of statistically significant indications of instrument validity and reliability and any other statistically significant correlation data such as perceptions varying with interventions and demographic data.

**Summary**

Two EBP protocol interventions were used with the intent to decrease false alarms and nuisance alarms in the RNICU and a survey instrument was piloted. A quasi-experimental time series design was used. Alarm observation and survey data were collected. Research 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 alarm observation and survey data collection were done; one pre-intervention and three post-intervention. Statistical analysis was done to determine if the EBP protocol interventions made statistically significant improvements in the incidence of nuisance alarms and false
alarms and to evaluate the survey tool. 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 600+ bed Magnet® hospital and utilized a 35-bed, Level III regional neonatal intensive care unit. The purpose of this translation research study was to decrease alarm fatigue and improve alarm safety in the RNICU. This was done through the implementation of EBP protocol interventions and piloting an RN survey instrument. The protocols used were the monitoring parameter EBP protocol and the electrode lead/pad and probe changing EBP 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. Pilot a survey tool designed to assess nurse understanding of alarm related terms and nurse perceptions of clinical alarms and alarm fatigue.
5. 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, 3, and 4. As discussed previously, alarm 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 alarm observation 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 H. 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. RNs from the intervention unit, RNICU, and other areas completed the survey across four waves of data collection. Nurse demographic descriptive statistics are in Table 4.

**Alarm Observation Data and Analysis**

The total number of alarms observed by research 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 baseline 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*

<table>
<thead>
<tr>
<th></th>
<th>Wave 1</th>
<th>Wave 2</th>
<th>Wave 3</th>
<th>Wave 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total # of alarms observed during data collection</td>
<td>420</td>
<td>228</td>
<td>201</td>
<td>187</td>
</tr>
<tr>
<td>Avg. # of all alarms per hour per bed (Change from Wave 1)</td>
<td>22.88</td>
<td>13.23</td>
<td>12.28</td>
<td>11.43</td>
</tr>
<tr>
<td>Adherence to Monitoring Parameter Protocol</td>
<td>n/a</td>
<td>95.71%</td>
<td>85.07%</td>
<td>98.48%</td>
</tr>
<tr>
<td>Total # of nuisance alarms observed during data collection</td>
<td>270</td>
<td>53</td>
<td>61</td>
<td>35</td>
</tr>
<tr>
<td>Average # of Nuisance alarms per hour per bed (Change from Wave 1)</td>
<td>14.71</td>
<td>3.08</td>
<td>3.73</td>
<td>2.14</td>
</tr>
<tr>
<td>Adherence to Electrode &amp; Probe changing Protocol</td>
<td>n/a</td>
<td>74.29%</td>
<td>76.12%</td>
<td>70.59%</td>
</tr>
</tbody>
</table>
Total # of false alarms observed during data collection

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<tbody>
<tr>
<td></td>
<td>68</td>
<td>30</td>
<td>36</td>
<td>26</td>
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</table>

Average # of false alarms per hour per bed (Change from Wave 1)

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</thead>
<tbody>
<tr>
<td></td>
<td>3.70</td>
<td>1.74</td>
<td>2.20</td>
<td>1.59</td>
</tr>
<tr>
<td>Change from Wave 1</td>
<td>↓ 53%</td>
<td>↓ 41%</td>
<td>↓ 57%</td>
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</table>

Total # of clinically relevant alarms observed during data collection

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<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>82</td>
<td>145</td>
<td>104</td>
<td>125</td>
</tr>
</tbody>
</table>

Average # of clinically relevant alarms per hour per bed

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<tbody>
<tr>
<td></td>
<td>4.47</td>
<td>8.42</td>
<td>6.35</td>
<td>7.64</td>
</tr>
</tbody>
</table>

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Nurse Survey Data and Analysis

The sample includes RNs in the RNICU, medical surgical unit, pediatrics unit, step down unit, and critical care floats (N = 180). The majority of surveys were completed by RNs from the RNICU (67%). Fifty percent of all RNs completing the survey reported being certified RNs, 68% are BSN prepared, and 99% of respondents were female.

Table 4

Nurse Demographic Descriptive Statistics

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years in Unit</td>
<td>9.53</td>
<td>9.57</td>
<td>0.00</td>
<td>36.00</td>
</tr>
<tr>
<td>Years as RN</td>
<td>13.23</td>
<td>10.61</td>
<td>1.00</td>
<td>37.00</td>
</tr>
<tr>
<td>Age</td>
<td>38.51</td>
<td>11.58</td>
<td>1.00</td>
<td>63.00</td>
</tr>
</tbody>
</table>

**Unit**

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical Care Floats</td>
<td>0.21</td>
<td>0.41</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>MedSurg</td>
<td>0.02</td>
<td>0.16</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Peds</td>
<td>0.07</td>
<td>0.25</td>
<td>0.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Alarm survey data showed that RNs perceived higher levels of alarm burden and alarm fatigue when caring for patients with higher acuity levels ($p < 0.0001$ for burden; $p < 0.0001$ for fatigue). RNs in medical-surgical units perceived the least amount of alarm burden and alarm fatigue, and RNs in critical care areas perceived the most. It was also noted that certified RNs were less likely to shut off or disable alarms ($p = 0.0003$).

There were 3 sub-scales in the survey: 1) RN Knowledge scale, 2) Alarm Risk Behaviors scale, and 3) Alarm Fatigue scale. Of primary interest were the Alarm Fatigue scale and the Alarm Risk Behavior scale. Over the 4 waves of data collection with the majority of respondents from RNICU, the average Alarm Fatigue Scale score decreased from 6.25 to 4.89. Additionally, the Alarm Fatigue Scale demonstrated strong internal
consistency as Cronbach $\alpha$ ranged from 0.845 to 0.981. The average Alarm Risk Behavior Scale scores also declined from wave 1 to wave 4. Excluding wave 2, the scale demonstrated good internal consistency as Cronbach $\alpha$ ranged from 0.727 to 0.930.

**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. Related to the RN survey, the Alarm Fatigue Scale and the Alarm Risk Behavior Scale demonstrated strong internal consistency. 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.
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.

Related to the RN survey that was piloted, the results indicate that a survey tool may be a reliable method for measuring alarm fatigue and alarm risk behaviors. As such,
the tool may be a relatively easy and cost-effective way to measure the impact of interventions designed to decrease alarm fatigue and improve alarm safety. Additional study is needed as the initial findings indicate that further instrument development is warranted. An alarm fatigue survey tool could contribute to improving alarm safety.

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 translated to the physiological monitoring of neonates to decrease both nuisance and false alarms. The protocols and findings from this study 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.

As indicated above, there are also implications from this project for further study. Ideally, this project should be replicated in other NICUs. This type of 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. There is also more to learn about alarm fatigue from the RN perspective and experience; this type of information could be gleaned with further survey instrument development. 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 a 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 months 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 and RN survey from this epidemiological approach could provide a large amount of information related to effectiveness of the EBP protocols and the survey tool 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 for the alarm data. 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. Additionally, survey response rates decreased over time with limited responses from RNs outside of the RNICU.

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, the survey instrument, 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.
Summary and Conclusions

This was a successful study. 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 survey tool shows promise for being a valid and reliable instrument for assessing alarm fatigue. 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 is 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, further develop the survey instrument, 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


Appendix A: Alarm Definitions for Conceptual Model

<table>
<thead>
<tr>
<th>Term</th>
<th>Conceptual Definition*</th>
<th>Operational Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alarm</td>
<td>Sound, light, and/or vibration that alerts, gives notice; i.e. fire alarm, telephone sound or vibration</td>
<td>n/a</td>
</tr>
<tr>
<td>Clinical Alarm</td>
<td>An alarm in the clinical or patient care setting; i.e. IV pump alarm, feeding pump alarm, patientcontrolled analgesia alarm, fall sensor, physiological alarms such as vital sign monitor alarm or pulse oximetry monitor alarm</td>
<td>n/a</td>
</tr>
<tr>
<td>Physiological Alarm</td>
<td>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</td>
<td>n/a</td>
</tr>
<tr>
<td>Clinically Relevant Alarm</td>
<td>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</td>
<td>Objective: observation of alarm related to clinical parameter that is clinically relevant; attention to patient is priority and care is provided to the patient</td>
</tr>
<tr>
<td>Nuisance Alarm</td>
<td>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</td>
<td>Objective: observation of alarm related to clinical parameter that is not clinically relevant; person tends to equipment, not patient</td>
</tr>
<tr>
<td>False Alarm</td>
<td>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</td>
<td>Objective: observation of alarm unrelated to clinical parameter; person tends to equipment, not patient</td>
</tr>
<tr>
<td>Alarm Workload</td>
<td>Work needed to attend to alarms; consists of clinically relevant alarms, nuisance alarms and false alarms; workload may be distributed across numerous persons</td>
<td>Objective: total number of alarms in a given area over a given amount of time</td>
</tr>
</tbody>
</table>
| **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).*

## Appendix B: Summary of Analyzed Articles

<table>
<thead>
<tr>
<th>Citation*</th>
<th>Conceptual Framework/ Theory</th>
<th>Main Finding</th>
<th>Research Method</th>
<th>Strengths of Study</th>
<th>Weaknesses</th>
<th>Level of Evidence**</th>
</tr>
</thead>
<tbody>
<tr>
<td>AACN, 2013</td>
<td>None</td>
<td>Practice Recommendations for alarm management</td>
<td>Clinical Practice Guidelines based on literature review</td>
<td>Uses AACN evidence guidelines</td>
<td>Does not speak specifically to application of EBP to neonates</td>
<td>Varies by recommendation</td>
</tr>
<tr>
<td>Cvach, 2012</td>
<td>The John Hopkins Nursing EBP Model (Nurse study)</td>
<td>5 themes in the research evidence; 2 in the non-research evidence; provides overview of areas for future research</td>
<td>Integrative review</td>
<td>Uses the John Hopkins Nursing EBP Model as a framework; describes literature search in details; organizes information found into themes</td>
<td>Does not offer definitions for all key terms/concepts</td>
<td>5/C</td>
</tr>
<tr>
<td>Konkani, Oakley, Bauld, 2012</td>
<td>None (Non-nurse study)</td>
<td>Organization of literature into 4 themes</td>
<td>Integrative review</td>
<td>Implications for alarm protocols, individual alarm settings, future research</td>
<td>No theoretical or conceptual framework</td>
<td>5/C</td>
</tr>
<tr>
<td>Gross, Dahl, Nielsen, 2011</td>
<td>None (Non-nurse study)</td>
<td>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</td>
<td>Observational, retrospective evaluation of alarm frequency</td>
<td>Sample size of 4104 patients</td>
<td>No theoretical or conceptual framework</td>
<td>6/C</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Study Type</td>
<td>Methodology</td>
<td>Findings</td>
<td>Conclusion</td>
<td>Level of Evidence</td>
<td></td>
</tr>
<tr>
<td>-----------</td>
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<td>-------------</td>
<td>----------</td>
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<td></td>
</tr>
<tr>
<td>Graham &amp; Cvach, 2010</td>
<td>Nurse Study</td>
<td>Clinical monitor alarms reduced by 43% through adjustments to default settings, individualizing alarm parameters, implementing monitoring policy</td>
<td>Small tests of change for quality improvement</td>
<td>Clinically relevant reduction in alarms</td>
<td>6/C</td>
<td></td>
</tr>
<tr>
<td>Cvach, Biggs, Rothwell &amp; Charles-Hudson, 2013</td>
<td>Nurse Study</td>
<td>Not specifically stated; did use John Hopkins evidence assessment tools</td>
<td>Avg. alarm per bed per day decreased by 46% related to implementation of a daily electrode change protocol</td>
<td>Description of literature review and QI rapid change pilot study</td>
<td>6/C</td>
<td></td>
</tr>
<tr>
<td>Henneman, Gawinski &amp; Giuliano, 2012</td>
<td>Nurse Study</td>
<td>Adapted Eindhoven Model of error recovery</td>
<td>More than monitoring is needed; the role of surveillance in improving patient safety</td>
<td>Descriptive/ case study as exemplar</td>
<td>6-7/E</td>
<td></td>
</tr>
<tr>
<td>Borowski, M. et al, 2011</td>
<td>Non-nurse study</td>
<td>None</td>
<td>Made the case for too many alarms and too few alarms; discussed clinical relevance of alarms, alarm fatigue and alarm</td>
<td>Based on a position paper that includes summary of expert opinions and review of 9 studies addressing true positive alarms and Good comparison of studies done related to true positive alarms and false positive alarms; gives recommendation for further research; German author-demonstrates alarm issues are international</td>
<td>7/E</td>
<td></td>
</tr>
<tr>
<td>Related Workload</td>
<td>False Positive Alarms</td>
<td>Summary of Research</td>
<td>Literature Strategy</td>
<td>For Purpose of Translation Study, this is More Technical Than Clinical; Diagram/Model/Concept Map Would Be Helpful Related to Discussion on Alarm Philosophy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>-----------------------</td>
<td>---------------------</td>
<td>---------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edworthy, J., 2012</td>
<td>None (Non-nurse Study)</td>
<td>Summary of research that is applicable to the design of auditory alarms in the medical context</td>
<td>Literature Review strategy outlined; discusses “alarm philosophy”—thinking of alarms as a whole; offers recommendations; 80 references</td>
<td>For purpose of translation study, this is more technical than clinical; diagram/model/concept map would be helpful related to discussion on alarm philosophy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cvach, M., Frank, R., Doyle, P., &amp; Stevens, Z., 2013</td>
<td>Alarm escalation algorithm (Nurse Study)</td>
<td>Algorithm and pagers improved response time and decreased alarm fatigue; also decreased noise at patient bedside</td>
<td>QI methodology to test intervention</td>
<td>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</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harris, R., Manaviza deh, J., McPherson, D., &amp; Smith, L., 2011</td>
<td>None (Nurse Study)</td>
<td>Focus on cardiac alarms; burst page alarm reduced delays in response time and saw decrease in burst alarms over time</td>
<td>QI methodology</td>
<td>Included review of the evidence; identified areas for further work; Limited generalizability given QI approach; no theoretical or conceptual framework</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*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: Research Assistant Orientation

Objectives:

1. Research Assistants (RAs) will be oriented to the layout of the RNICU

2. RAs 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. RAs will be able to identify the type of alarm sounds they will hear for each of the parameters being measured.

4. RAs will be able to state the difference between false, nuisance, and clinically relevant alarms and accurately identify these types of alarms.

5. RAs 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. RAs 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

- RAs will practice data collection simultaneously with each other and the instructor
- Results will be compared and variations discussed
- RAs will perform data collection for competency evaluation
- RAs will be orientated to data entry
Appendix E: Alarm Observation Data Collection Sheet – Preintervention

<table>
<thead>
<tr>
<th>Type of Monitoring (Check all that apply)</th>
<th>Total Number of Alarms</th>
<th>Code each alarm event as follows:</th>
<th>Notes/Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>E: Nurse intervention for equipment</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>P: Nurse intervention for patient</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>B: Nurse intervention for both equipment and patient</td>
<td></td>
</tr>
<tr>
<td>Respiration</td>
<td></td>
<td>False Alarm*</td>
<td></td>
</tr>
<tr>
<td>BP</td>
<td></td>
<td>Nuisance Alarm**</td>
<td></td>
</tr>
<tr>
<td>Pulse Ox/O2 Sat</td>
<td></td>
<td>Clinically Relevant Alarm***</td>
<td></td>
</tr>
<tr>
<td>HR/ELG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vent/IMI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPAP/RAM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitric Oxide</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTALS</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*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

<table>
<thead>
<tr>
<th>Type of Monitoring</th>
<th>Total Number of Alarms</th>
<th>Code each alarm event as follows:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>E: Nurse intervention for equipment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>P: Nurse intervention for patient</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B: Nurse intervention for both equipment and patient</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>False Alarm*</th>
<th>Nurse Alarm**</th>
<th>Clinically Relevant Alarm***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulse Ox/O2 Sat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR/ECG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vent/CRV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPAP/RAM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitric Oxide</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTALS</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

**Nurse 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 intervention (i.e., meds, change in therapy or position, suctioning)
Appendix G: Nurse Survey

Nurse Survey on Clinical Alarms and Alarm Fatigue

This survey is voluntary and results are confidential. Participation by completing and returning the survey indicates consent for participation in the study.

The purpose of this survey is multifactorial. Some questions are to determine the types of alarms seen with the patients you care for and to assess understanding or use of alarm related terms. Additional questions are to determine your perceptions of clinical alarms and alarm fatigue. The results of this study will be used to further understand alarm related terms/concepts and to further develop a valid and reliable tool to assess nurse perceptions of alarm fatigue. A valid and reliable tool to assess alarm fatigue would be helpful in future studies of interventions designed to decrease alarm fatigue and improve alarm safety.

Part I (Alarm Terms and Patient Care)

Please circle the letter that corresponds to your response.

1. Alarms that go off for non-clinically relevant reasons such as loose leads or patient movement are false alarms.
   - Agree (A)
   - Unsure (U)
   - Disagree (D)

2. I care for patients that have false alarms.
   - Agree (A)
   - Unsure (U)
   - Disagree (D)

3. Alarms that go off because the settings are not relevant to the patient are nuisance alarms.
   - Agree (A)
   - Unsure (U)
   - Disagree (D)

4. Alarms that go off because the settings are not specific enough to recognize a problem for a particular patient are nuisance alarms.
   - Agree (A)
   - Unsure (U)
   - Disagree (D)

5. I care for patients that have nuisance alarms.
   - Agree (A)
   - Unsure (U)
   - Disagree (D)

6. Alarms that indicate that care or intervention is needed for the patient are clinically relevant.
   - Agree (A)
   - Unsure (U)
   - Disagree (D)

7. I care for patients that have clinically relevant alarms.
   - Agree (A)
   - Unsure (U)
   - Disagree (D)

8. Alarms add to the work load of RNs.
   - Agree (A)
   - Unsure (U)
   - Disagree (D)

9. Alarm burden exists when the number of alarms is challenging to keep up with.
   - Agree (A)
   - Unsure (U)
   - Disagree (D)

10. False alarms increase alarm burden.
    - Agree (A)
    - Unsure (U)
    - Disagree (D)
11. Nuisance alarms increase alarm burden. A U D
12. Over time, alarm burden can lead to alarm fatigue. A U D
13. Alarm fatigue compromises alarm safety. A U D

Part II (Perceptions and Behaviors)

Please circle the number that corresponds to your response.

15. In my work area, I can tell clinical alarms apart by sound only.

   0 Never          1 Rarely        2 Sometimes     3 Often         4 Always

16. In my work area, all of the clinical alarms have distinguishing sounds.

   0 Never          1 Rarely        2 Sometimes     3 Often         4 Always

17. I have delays in responding to clinical alarms.

   0 Never          1 Rarely        2 Sometimes     3 Often         4 Always

18. I have failed to respond to clinical alarms.

   0 Never          1 Rarely        2 Sometimes     3 Often         4 Always

19. I have silenced clinical alarms without assessing the patient.

   0 Never          1 Rarely        2 Sometimes     3 Often         4 Always

20. I have silenced clinical alarms while assessing or caring for the patient.

   0 Never          1 Rarely        2 Sometimes     3 Often         4 Always

21. I have shut off or disabled clinical alarms.

   0 Never          1 Rarely        2 Sometimes     3 Often         4 Always

22. I have more clinical alarms every shift than I can easily manage.

   0 Never          1 Rarely        2 Sometimes     3 Often         4 Always

23. I have more clinical alarms every hour than I can easily manage.

   0 Never          1 Rarely        2 Sometimes     3 Often         4 Always

Please rate your level of the following:

   None                          High

24. My alarm work load

   0 1 2 3 4 5 6 7 8 9 10

25. My alarm burden level

   0 1 2 3 4 5 6 7 8 9 10

26. My alarm fatigue level

   0 1 2 3 4 5 6 7 8 9 10
**Part III (Frequency)**

Related to your most recent shift, please circle the option that corresponds to your response.

27. I have been delayed in responding to clinical alarms _____ times during my last shift
   - 0 1-5 6-10 11-15 16-20 21-25 25+

28. I have not responded to clinical alarms _____ times during my last shift
   - 0 1-5 6-10 11-15 16-20 21-25 25+

29. I have silenced clinical alarms _____ times during my last shift without assessing the patient.
   - 0 1-5 6-10 11-15 16-20 21-25 25+

30. I have shut off or disabled clinical alarms _____ times during my last shift
   - 0 1-5 6-10 11-15 16-20 21-25 25+

**Demographics**

Please fill in the blank or mark the option that corresponds to your response.

31. What is your Caregiver (associate) number? _______________

32. What unit do you work on? _______________

33. What shift do you work on?
   - □ Days □ Nights □ Both/flex shifts

34. How many years have you worked on this unit? _____

35. How many years have you been an RN? _____

36. What is your age in years? _____

37. Are you male or female?
   - □ Male □ Female
Continued

38. What is your race/ethnicity?
   - White
   - Asian
   - African American
   - Hispanic

39. Please mark all education that applies:
   - Diploma
   - ADN
   - BSN
   - MSN
   - Doctorate
   - Other: _______

40. Are you a certified nurse?  
    - Yes
    - No

41. Is there anything else about alarms that you would like to tell us that we haven’t asked you about? If so, please use the space below to write out your comments.

Thank you for completing this survey.

Please put completed surveys in the envelope marked for Piper Probst.
Appendix H: Range, Median, and Mode for Alarm Observation Data

<table>
<thead>
<tr>
<th>For Alarm Observation Data Collected</th>
<th>Wave 1</th>
<th>Wave 2</th>
<th>Wave 3</th>
<th>Wave 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All Alarms</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>0–21</td>
<td>02–1</td>
<td>0–13</td>
<td>0–23</td>
</tr>
<tr>
<td>Median</td>
<td>4.5</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mode</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>False Alarms</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>0–12</td>
<td>0–6</td>
<td>07–</td>
<td>05–</td>
</tr>
<tr>
<td>Median</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mode</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Nuisance Alarms</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>02–1</td>
<td>0–14</td>
<td>0–13</td>
<td>01–0</td>
</tr>
<tr>
<td>Median</td>
<td>1.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mode</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Clinically Relevant Alarms</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>0–9</td>
<td>0–21</td>
<td>0–13</td>
<td>0–23</td>
</tr>
<tr>
<td>Median</td>
<td>0</td>
<td>0.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mode</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>