

PEDIATRIC MEANINGFUL ALARM MANAGEMENT APPROACH

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ABSTRACT

Jessie McBride Gilmore: Pediatric Meaningful Alarm Management Approach
(Under the direction of Debbie Travers)

The North Carolina Children's Hospital staff on an acute care pediatric general medicine floor are subject to unnecessary physiological monitor alarming and are at high risk for alarm fatigue. Pediatric clinicians are faced with the daunting task of determining appropriate age-based vital sign parameters and often fail to order suitable vital sign parameters or correctly program physiological monitors. This breakdown in care magnifies the importance of implementing meaningful alarm use to reduce alarm fatigue in clinicians caring for pediatric patients and to prevent clinically significant adverse events through early detection.

This project was a quality improvement study with the objective to improve cardiorespiratory monitor parameter practice adherence among clinicians through education. The first phase collected retrospective patient data to determine clinician adherence and to fully understand the burden of alarm fatigue on an inpatient acute care unit. Clinician adherence was measured by comparing electronic health records to physiological monitor settings and the relevance to actual patient data. The second phase analyzed the baseline data and applied the Institute for Healthcare Improvement's Model for Improvement. After project completion, the intent was to have increased alarm parameter adherence and hence decreased alarm fatigue on the unit.

I found a significant lack of alarm parameter adherence among the nursing staff. The alarm parameters routinely did not match the orders for each patient, and as a result, the patients alarmed excessively or had wider alarm parameter settings than what was ordered for

them. This project highlighted the need for parameter customization for every child, using the default age groups as a guide for parameter orders. The average minimum respiratory rate value registered lower than the default alarm settings for all age groups, which indicates a strong association with the total number of low respiratory rate alarms.

The intervention implemented in this project included strong emphasis on staff education for nurses and physicians. Also included were recommendations for policy and practice changes of physiologic monitoring, which remain in process and are expected to continue longer than the timeline of this project.

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LIST OF ABBREVIATIONS

6CH	6 Children's
AACN	American Association of Critical Care Nursing
CCT	Classical Conditioning Theory
CSE	Clinically Significant Events
DNP	Doctorate of Nursing Practice
ECRI	Emergency Care Research Institute
FDA	Food Drug Administration
HR	Heart Rate
IHI	Institute for Healthcare Improvement
NA	Nursing Assistant
NC	North Carolina
PDSA	Plan Do Study Act (Cycle)
PMA	Pediatric Medical Team A
PMB	Pediatric Medical Team B
PMG	Pediatric Medical Team Gastroenterology
RN	Registered Nurse
RR	Respiratory Rate
SMPC	Synergy Model for Patient Care
SpO ₂	Pulse Oximetry
TJC	The Joint Commission
UNCH	University of North Carolina Healthcare

CHAPTER 1: BACKGROUND

Introduction

The number of alarm-equipped medical devices used to assist patient care is rising with technological advances, contributing to an exponential growth of alarm systems. Alarms help improve patient safety by serving as early warnings for clinicians. However, with frequent alarms, clinicians are overwhelmed by noise stimuli, which contribute to desensitization to alarms, known as alarm fatigue (West, Abbott, & Probst, 2014). Alarm fatigue tempts clinicians to turn down alarm volumes, widen parameter settings, or shut off alarms entirely; this can lead to delayed responses in care and increased risk for poor patient outcomes (The Joint Commission [TJC], 2013a). The Joint Commission (TJC) reports that 98 of almost 4,000 reported sentinel events occurring between 2009 and 2012 were related to alarm fatigue, with 80 of these events ending in death and deemed avoidable if proper policies and procedures were in place (TJC, 2013a; TJC, 2016). Other poor patient outcomes stemming from alarm fatigue include permanent loss of patient function, unexpected additional care of condition caused by a missed alarm, and extended care with longer length of stay (TJC, 2013a). These poor patient outcomes create strong financial burdens for hospital reimbursement and patient health care payments (TJC, 2013a). Although alarm fatigue is considered a low volume problem, it poses high risks for patients and clinicians and remains a tough problem to manage in the health care setting. Alarm fatigue also influences patient satisfaction measures when it affects patient sleep and anxiety, as well as that of family members or significant others accompanying the patient.

Problem

Approximately 95% of physiological alarms in pediatric patients are false positive alarms and are classified as non-actionable, or not requiring intervention (Dandoy et al., 2014). Prior to discussing the alarm fatigue problem, it is important to classify the four possible outcomes related to physiological alarms. They include true positive alarms, true negative alarms, false positive alarms, and false negative alarms. True positive alarms are alarms that signal attention and complement clinical signs or symptoms. The goal of alarm-equipped devices is to alert caretakers of patient deterioration, which is reflected with true positive alarms. True negative alarms indicate no alarms present and no patient clinical signs or symptoms. False positive alarms are represented by alarms that do not have matching clinical signs or symptoms. False positive alarms cause caretakers to spend unnecessary time addressing alarms and contribute to alarm fatigue. False negative alarms are when no alarm signals and the patient has clinical signs or symptoms—which causes missed patient outcomes and potential sentinel events.

The staff of 6 Children's (6CH), an acute care pediatric, general medicine floor within the North Carolina (NC) Children's Hospital, are subject to unnecessary physiological monitor alarming and are at high risk for alarm fatigue. Six Children's was the setting for this project. In pediatrics, the range of developmental stages and vital sign parameters combined with young patients actively in motion contribute to excessive alarming. Pediatric clinicians are faced with the daunting task of determining appropriate age-based parameters and often fail to order suitable vital sign parameters or correctly program physiological monitors. This breakdown in care magnifies the importance of implementing meaningful alarm use to reduce alarm fatigue in clinicians caring for pediatric patients and to prevent clinically significant adverse events through early detection.

Will a data-driven alarm management intervention lead to improved meaningful alarm use among clinicians caring for hospitalized acute care pediatric patients? A localized quality improvement study discovered that when they implemented standardized team-collaborative alarm management on a pediatric acute care in-patient floor, adherence with meaningful alarm use increased (Dandoy et al., 2014). This can lead to a reduction in alarm fatigue and risk for poor patient outcomes (Dandoy et al., 2014).

Preliminary Data

Previous work performed by a University of North Carolina School of Nursing honors student collected alarm frequency data on all audible alarms in regards to heart rate, respiratory rate, and pulse oximetry. The honors student identified that approximately 5 alarms are signaled per nurse per hour on 6CH, indicating a strong alarm presence and need for practice reformation (Fry, 2015).

Purpose Statement

The purpose of this project is to develop a standardized, team-collaborative alarm management intervention aimed at reducing alarm fatigue, caused by false-positive physiological alarms stemming from incorrect alarm parameter use among clinicians on a pediatric acute care unit.

Review of Literature

A review of literature was conducted to describe the state of science on alarm fatigue and meaningful alarm management.

Search Strategy

The literature search was done using three databases: PubMed, CINAHL, and Embase. The mesh terms used for the search included: alarm fatigue OR alarm desensitization OR

cardiopulmonary monitor* OR clinical alarm* OR monitor alarm* OR alarm management OR alarm safety. Included articles discussed cardiopulmonary alarms, adult and pediatric patients, in-patient hospitalizations for acute and critical care, and involved nursing staff or other health care related fields. Exclusion criteria included articles greater than 10 years old, non-cardiopulmonary alarms such as ventilator, bed, and intravenous pump alarms, non-English language, no discussion of alarm fatigue or desensitization, and any studies involving the emergency room or operating room. The literature search resulted in a total of 286 articles with 40 being full-text accessible. After applying the exclusion criteria, 18 articles were used to conduct the review of literature. The PRISMA 2009 Flow Diagram was used to summarize the literature search and is illustrated in Appendix A.

Evidence-Alarm Fatigue

TJC reports that 85% to 99% of alarms are false positives and do not require attention or intervention (TJC, 2013a). The most common causes of false alarms are the use of default parameter settings; lack of patient population customization; and improper electrode placement, maintenance, and skin preparation (American Association of Critical-Care Nurses [AACN], 2013; TJC, 2013a). One study examined the rate of clinically significant events (CSE) and false alarms on a 20 bed Pediatric Intensive Care Unit during a 45-day time span (Talley et al., 2011). They identified a total of 2,245 high priority alarms with only 68 (3%) of these alarms deemed clinically significant and required interventions (Talley et al., 2011). The study results illustrate the challenge of inpatient monitoring and emphasize the importance of the clinical judgement that clinicians must use to properly identify the few life-saving alarms among an abundance of false alarms.

In 2010, alarm fatigue was brought to public attention when a patient died as a result of a

physiological alarm being turned off at Massachusetts General Hospital (Cvach, 2012). Federal reports indicated that nursing staff were subjected to constant beeping—causing alarm desensitization, which contributed to the patient’s fatal outcome (Cvach, 2012).

Hospital Policy Implications

Alarm fatigue impacts every hospital-based clinician that utilizes or is exposed to alarm-equipped devices, which led TJC to develop NPSG.06.01.01, a National Patient Safety Goal for 2014 focused on alarm fatigue prevention (TJC, 2013a). The purpose of this initiative was to decrease wide-spread desensitization and potential for patient safety threats (TJC, 2013a). TJC states that even though there is not a universal solution, to meet accreditation criteria, it is requiring hospitals to internally develop policies to promote standardization and alarm management customization for patients (TJC, 2013b).

The first phase of NPSG.06.01.01, initiated in January 2014 requires all hospitals to identify alarm safety as a priority and categorize significant alarms based on feedback from staff, patient risk if alarm is ignored, comparison between essential and nonessential alarms, alarm-related incident history, and evidence based practices (TJC, 2013b). The second phase launched in January 2016 and required hospitals to develop and implement policies and procedures that address appropriate settings for certain patient populations, alarm signal disabling, changing parameters, authority for alarm signal ordering and manipulation, monitoring and responding to signal expectations, tailoring alarms to the individual patient, and discontinuation of monitoring devices (TJC, 2013b). This phase also required hospitals to develop a clear strategy for alarm management education for initial and ongoing education needs for all hospital employees caring for patients (TJC, 2013b).

In response to TJC's call for policy action and to develop methods in reducing alarm fatigue, the patient safety officer at UNCH formed an alarm safety committee comprised of critical care representatives. After meeting with the patient safety officer and attending a committee meeting it was evident that the hospital's primary focus is on the critical care setting. Currently there are no plans for interventions in acute care, or more specifically acute pediatric care.

Causes of Alarm Fatigue

The root cause of alarm fatigue is the excessive false-positive alarms generated by physiological monitoring. Even though false-positive alarms are a multi-faceted problem, research narrows to two main causes: inefficient alarm parameter settings and configuration and equipment malfunction.

The Emergency Care Research Institute (ECRI) identified inadequate alarm configuration policies and practices as the number one health technology hazard of 2015 (Emergency Care Research Institute [ECRI], 2014). As a result, they compiled evidence on causes of alarm fatigue and recommendations focusing on creating or reassessing policy for alarm configuration practices (ECRI, 2014). Alarm configuration practices include using default alarm parameter and volume settings and using the correct process to change alarm parameter settings (ECRI, 2014). The standard process to change alarm parameter settings addresses who has the authority, what circumstances, how to change settings, reactivation of default settings, and intermittent audits of configuration settings (ECRI, 2014).

There is strong evidence that the primary cause of excess alarms in children are related to incorrect alarm parameter settings (Bonafide et al., 2013; Burgess, Herdman, Berg, Feaster, & Hebsur, 2009; Talley et al., 2011). One team of pediatric physicians concluded that 40% of

respiratory rate and 54% of heart rate observations fell outside textbook reference ranges for pediatrics, which influenced the need to develop evidence-based vital sign ranges for children (Bonafide et al., 2013). A major challenge in alarm management is delineating who has the responsibility for changing alarm parameter settings, which indicates a need to identify who has the authority, circumstances, knowledge and training to change settings, and reactivation of default settings (Cvach, 2012; ECRI, 2014). Many organizations do not assign the alarm parameter configuration responsibility to a specific profession or designee. Also, there are not practice standards to dictate alarm management, leaving a gray area open for interpretation, which creates poor communication and alarm management. Routine nursing practices focused on continuous physiological monitors include checking alarm parameters and volumes at the beginning of the shift to ensure proper patient safety, but many nurses do not complete this task. One study observed only 61% of nurses properly checking alarm parameter orders and setup, citing this as a low priority focus for nurses at the beginning of a shift (Gazarian, 2013). Performing intermittent audits of configuration settings can promote accountability and increase parameter adherence (ECRI, 2014). Developing specific protocols for alarm configuration creates a standardized approach to managing alarm systems. These protocols define appropriate parameters for each patient and allow caregivers to identify inappropriate alarms quickly, which can lead to efficient, patient-centered care and reduce noise stimulation that caregivers are exposed to (ECRI, 2014). Though specific protocols for alarm configuration contribute to patient customization and reduction in noise stimulation, other technological nursing interventions must be considered to address the problem of alarm fatigue related to frequent false alarms.

Another cause of false positive alarms is because of equipment malfunction or user error (AACN, 2013). Designing equipment-related interventions is predicted to reduce false positive

alarm activity (AACN, 2013). Drew et al. (2014) determined that 89% of all false positives alarms are attributed to inappropriate user settings, lack of regard to patient condition, and equipment deficiencies. Balancing sensitivity and specificity based on the signal detection theory can promote more ergonomic physiological alarms (Raymer, Bergstrom, & Nyce, 2013). Alarm sensitivity is the ability of the monitoring system to detect abnormal events and has threshold settings used to identify these events (Raymer, Bergstrom, & Nyce, 2013). The alarm specificity of the monitoring systems ensures that no inaccurate alarms are set off and utilizes customized delay settings that prevent nuisance alerts (Raymer, Bergstrom, & Nyce, 2013). Biomedical technology professionals suggest policies consider customizing delay and threshold settings for pulse oximetry, allowing sensors to self-correct when a patient is in motion and decrease the sensitivity to prevent quick-firing alarms—a problem often seen in pediatric patients (AACN, 2013; Hu et al., 2012).

In an observational study examining alarm-related nursing interventions, 19% of all alarms were caused by equipment failure (Gazarian, 2013). Equipment failures include dried out electrodes, improper electrode contact with skin, or interference signals due to patient movement or tangled wires. Proper skin preparation is critical for electrode contact, and it is recommended that electrodes need to be assessed and changed daily or per manufacturer instructions (AACN, 2013). Pediatric patients require specific attention to proper equipment set up and maintenance since this population is most likely to pull, tangle, or soil electrode leads and wires.

According to the literature, the major causes of alarm fatigue are attributed to incorrect alarm parameter configuration practices across all disciplines and equipment issues related to the balance between specificity and sensitivity, clinician error, and improper equipment use.

Interventions to Optimize Alarm Use

To address alarm fatigue and ensure proper alarm use, pediatric inpatient clinicians must be presented with a standardized alarm management approach vertically by upper management and horizontally across multiple disciplines (Cvach, 2012). Organization leadership involvement in planning and enforcing alarm management plays a large role in success of tackling alarm fatigue and improving patient outcomes. In response to the TJC instituting alarms as a National Patient Safety Goal for 2014, it has been suggested that organizations focus leadership and organizational planning for alarm management implementation (Cvach, 2012; TJC, 2013a). A priority-setting process for technology implementation must be adopted by hospitals, instead of buying an alarm-equipped device and tailoring the alarm management process to the device (TJC, 2013a). The development of a reporting system that shares information regarding alarm-related incidents, prevention strategies, and lessons learned from the experience will ensure hospital accountability and communal knowledge (TJC, 2013a). The system would be shared with the Association for the Advancement of Medical Instrumentation (AAMI), ECRI, Food Drug Administration (FDA), and TJC (TJC, 2013a). Hospital leadership must also develop a strong education program that is implemented among all staff upon initial hiring and provide annual refresher classes to re-emphasize the alarm management intervention content (Cvach, 2012). In combination with organizational leadership, it is necessary to involve the inter-professional team.

Using an inter-professional approach in intervention development ensures a multi-dimensional protocol. It is recommended that hospitals form an inter-professional team to examine alarm safety and the impact of alarm fatigue, create a process for continual optimization of alarm system policies, review trends in alarm related events and areas of needed improvement,

and implement an alarm management policy (AACN, 2013; ECRI, 2014; TJC, 2013a). One study demonstrated a reduction in false alarms by using a team-based approach (Dandoy et al., 2014). The investigators developed an inter-professional team that created a cardiac monitor care process focused on ordering age-appropriate parameters, daily individualized parameter settings checks, and a method for discontinuation, which was communicated amongst team members via a monitor log (Dandoy et al., 2014). As a result of a standardized protocol and increased communication regarding alarm parameters, the median number of alarms decreased from 180 alarm signals a day to 40—an 80% decrease in alarms per patient per day (Dandoy et al., 2014). Another localized, unit-driven study discovered a 43% reduction rate in alarms after implementing an inter-professional staff retraining program, revising default settings, and updating software (Graham & Cvach, 2010). All disciplines are affected by false alarms and agree that it is a significant patient safety issue that is a priority to the health care team (Funk, Clark, Bauld, Ott, & Coss, 2014). A standardized alarm management intervention that opens the line for clear and consistent communication across the care team significantly reduces alarm frequency and fatigue.

Technology Solutions to Alarm Fatigue

A third-party alarm notification system serves as an alternative solution to alarm fatigue. Some hospitals choose to develop a system that removes alarms entirely from the floors and places them in a monitoring station. These stations have traditionally been overseen by staff members not taking care of patients. Research indicates that systems using central alarm management data have not shown significant differences in mortality (Cvach, 2012). Technology advancements have allowed scientists to create an electronic third-party notification system that collects signals from devices and sends messages to the phone or pager of a clinician based on a

programmed escalation system (Kokani, Oakley, & Bauld, 2012). The main benefits of this system are that it minimizes the human element of alarm manipulation and decreases clinician exposure to alarms, which reduces alarm fatigue and increases patient safety. This technology has the ability to utilize smart alarms, meaning the system would learn patient patterns and operate on a feedback loop, decreasing alarm signals (Cvach, 2012). On the other hand, third-party notification systems can create a delay in care, and the system can fail if one component fails (Kokani, Oakley, & Bauld, 2012). There is little research to date on these types of systems, and the FDA requires purchase approval for all hospitals since the devices are classified as Class II risk management (Kokani, Oakley, & Bauld, 2012).

Cutting-edge technology can also improve alarm frequency with smart alarm systems that learn from a patient's baseline and make adjustments without human intervention and contact-free sensors that assess a patient's condition, shown to reduce patient influenced excess alarms (Kokani, Oakley, & Bauld, 2012; Tahir, 2015). These new technologies are still being tested and have not been fully studied to show high efficiency.

Theoretical Framework

Alarm fatigue is a multi-dimensional problem that requires incorporation of theories and models to understand why it occurs and the effect it has on patient care. Ivan Pavlov's Classical Conditioning Theory (CCT) explains the problematic relationship between health care clinicians' learned behavior and over-abundance of alarms generated by devices used for clinical warnings (Braungart & Braungart, 2015). The American Association of Critical-Care Nurses (AACN) Synergy Model for Patient Care (SMPC) framework illustrates the theory of planned intervention to ease alarm fatigue through an alarm management approach. This theory focuses on the relationship among patient characteristics, nurse competencies, and health care system

characteristics to achieve positive patient outcomes and is the driving theory for the intervention used in this project (Walsh-Irwin & Jurgens, 2015).

Classical Conditioning Theory

Pavlov's CCT is a behaviorist learning theory from the field of Psychology (Braungart & Braungart, 2015). CCT explains the phenomenon of changing behavior related to simple stimulus and response relationships (Braungart & Braungart, 2015). All living organisms start with a naturally occurring stimulus and specific response, referred to as unconditioned stimuli and responses (Braungart & Braungart, 2015). The theory states that when an unrelated, neutral stimulus is introduced into the unconditioned sequence over a period of time, it promotes learned behavior and alters the response. The resulting relationship is classified as the conditioned stimulus and conditioned response (Braungart & Braungart, 2015).

In applying CCT to alarm fatigue, the intended relationship between clinicians and alarms can be viewed as unconditioned, where the unconditioned stimulus is any life-threatening patient alarm and the unconditioned response is to assess the patient and determine if their health is at risk. Alarm desensitization develops when a neutral stimulus, such as false positive alarms or alarms that do not have corresponding clinical symptoms, resonates excessively and the response becomes conditioned. Clinicians learn to ignore or become less reactive to alarms, which leads to negative patient outcomes and consequences (Braungart & Braungart, 2015). Classical conditioning is used to explain the development of emotions such as fear and anxiety when one is exposed to an aversive stimulus that provokes an emotional response (Braungart & Braungart, 2015). Unnecessary alarms generate powerful workplace emotions including increased stress, agitation, anxiety, and exhaustion, all of which contribute to alarm fatigue.

AACN Synergy Model for Patient Care

The SMPC is a predictive, descriptive nursing theory developed in the 1990s by the AACN to describe nursing's role in providing care to critically sick patients (Curley, 1998). The model states that synergy occurs when more than one individual works towards a common goal (Curley, 1998). More specifically, the model predicts that when patient characteristics are accurately matched with appropriate nursing competencies, optimal patient outcomes will result (Arashin, 2010; Curley, 1998). To understand the nurse-patient relationship, the model cites eight patient characteristics that concern nurses and eight competencies that affect patients and outcomes on a tiered level system. The patient characteristics include: resiliency, vulnerability, stability, complexity, resource availability, participation in care, participation in decision making, and predictability (Curley, 1998). The nurse competencies include: clinical judgment, advocacy and moral agency, caring practices, collaboration, systems thinking, response to diversity, clinical inquiry, and facilitator of learning (Curley, 1998).

Since inception, the SMPC has been clinically applied in acute and critical care. The framework has influenced nursing management to rewrite the role of nursing and provide nurses with measurable competencies for individual growth and development (Kaplow, 2003; Kerfoot & Cox, 2005; Pacini, 2005). Hospitals have adopted the SMPC as their nursing conceptual framework to provide a uniform theory of practice and policy development (Gralton & Brett, 2012; Kaplow & Reed, 2008).

The SMPC has demonstrated increased interdisciplinary communication, positive patient outcomes, and patient and nurse satisfaction when applied to team-based interventions—a heavy focus for this project's intervention (Arashin, 2010; Kerfoot, Lavandero, Cox, Triola, Pacini, & Hanson, 2006). The SMPC guides interdisciplinary teams, which enhances collaborative

decision-making and ability to match appropriate care to patients' needs (Arashin, 2010). One research group used the SMPC to examine the relationship between proper skin preparation for electrode placement and frequency of alarms (Walsh-Irwin & Jurgens, 2015). They deduced that when nurses practice competently by customizing patient care related to alarms, alarm frequency and risk for poor patient outcomes are reduced (Walsh-Irwin & Jurgens, 2015).

Theoretical Framework Conclusion

The classical conditioning theory explains development of alarm fatigue in health care clinicians as a conditioned response to excessive false positive alarms. Patient outcomes are at stake and action must be implemented to correct learned behavior and protect patient safety. The AACN SMPC framework demonstrates that not one characteristic or competency can be isolated, and that everything is interconnected. Aligned patient characteristics, nurse competencies, and health care environments ensure successful implementation of a synergized team-based alarm management approach—the goal of this project.

Gaps in Literature

Since alarm fatigue is not widely studied in the pediatric setting, it is important for further research to describe the problem in the pediatric population and inform pediatric-specific interventions. Current literature only describes studies performed on pediatric intensive care units and does not address physiological monitoring in acute pediatric care and its effect on alarm fatigue. Also, with the lack of standardized vital signs for inpatient acute care pediatric age groups, it is difficult to set appropriate alarm parameter guidelines.

This project intends to address these gaps in current literature. After collecting pediatric specific alarm data and actual vital sign averages, enough evidence would exist to generate appropriate educational material to promote the reduction of false positive alarms.

CHAPTER 2: PROJECT METHODS AND INTERVENTION

Project Design

This Doctorate of Nursing Practice (DNP) project was a quality improvement study with the goal to improve physiological monitor practice adherence for pediatric patients on 6CH. The design of this study was partitioned into two phases. In the first phase, I collected retrospective patient data to determine clinician adherence on 6CH and fully understand the burden of alarm fatigue on 6CH. Clinician adherence was measured by comparing orders in the EHR to settings in the physiological monitors, and relevance to actual patient data. The second phase analyzed baseline data and applied the Institute for Healthcare Improvement's (IHI) Model for Improvement (Institute for Healthcare Improvement [IHI], n.d.). The Model for Improvement framework is a commonly used rapid cycle quality improvement strategy to achieve optimal clinical outcomes. The purpose of using the Model for Improvement was to accelerate an alarm parameter-centered approach that would improve the overall alarm management process among pediatric clinicians. Within this model, the Plan-Do-Study-Act (PDSA) cycle was used, which is a tool used to test change by creating a plan for change, testing the plan by doing, studying the results, and then making changes to the test by acting (IHI, n.d.). The short-term goal of this project was to increase alarm parameter adherence on 6CH, and in turn, decrease alarm fatigue on the unit. The long-term goal was that the project's outcome will lead to policy revision at UNCH.

Setting and Subjects

The project took place on 6CH within the NC Children's Hospital. The NC Children's Hospital cares for patients all over NC with a total of 150 inpatient beds and averages approximately 6,500 inpatient admissions per year (University of North Carolina Health Care [UNCH], 2015). Six Children's is a 24-bed acute care unit, caring for general medicine inpatient children ages 1 day to 18 years old. The unit employs 54 registered nurses (RN), 15 nursing assistants (NA), and 1 health unit coordinator and operates on a four-to-one patient to RN ratio and a twelve-to-one patient to NA ratio. Each room is a private room and includes individual physiological monitors that patients may or may not utilize depending on their diagnosis. The monitoring system used on 6CH is the Philips Intellivue. The physiological monitors contain four alarm-enabled physiological alarms: heart rate, respiratory rate, pulse oximetry, and blood pressure. Since blood pressure is only taken every 4 to 8 hours and not continuously monitored on 6CH, it was eliminated as a measured variable for this project.

Methods

Phase One: Baseline Data Collection

Prior to data collection, the project was exempted by the UNC Internal Review Board and accepted by the UNCH Nursing Research Council. Patients included in data collection were between the ages of 1 day old to 18 years old, admitted to the general pediatric clinician teams, Pediatric Medical Team A (PMA), Pediatric Medical Team B (PMB), and Pediatric Medical Gastroenterology (PMG), who had physiological monitoring for more than 24 hours. For the first data collection period, this project relied on chart reviews. Therefore, no patient interaction occurred and no changes to patient care were executed. All patient data and identifiers were protected during data collection by assigning a unique identification number to prevent subject

duplication. All clinicians that write orders in the EHR and translate the orders into the physiological monitors were included in this study as subjects through their contribution to alarms. Types of clinicians include physicians, nurse practitioners, nurses, and nursing assistants. Data collection did not include any identifying information on clinicians.

Phase Two: Interventions

After data analysis, nursing and medical team representatives were involved to determine the suitable intervention to address alarm parameter inefficiencies. Patients and their care were not affected by this project's intervention since the intervention built upon current clinician practices and did not change practice.

Monitoring Practices and Policies: Baseline

Pre-project practices regarding alarm parameter use were as follows: patient orders were communicated through default parameters in the EHR and assigned based on age range; the nurse was then responsible for translating the physician orders for vital sign parameters into the physiological monitors; and lastly if a patient's actual vital sign was outside the defaulted parameter range the nurse was responsible for notifying the physician to determine acceptable values. Appendix B outlines the expected nursing workflow regarding alarm parameter management.

Initial observations on 6CH indicated there were inconsistencies between EHR orders and actual parameter settings in the physiological monitors, resulting in unnecessary false alarms. Appendix C shows the default age-based pediatric parameters used in the EHR and the 'pediatric' default parameters used for the physiological monitors respectively. Since there was only one setting for the physiological monitor, it was guaranteed that the nurses had to manipulate the monitors to reflect the orders, as none of the default alarm parameters in the EHR

match the physiological pediatric profile. This created a workflow problem for nurses causing false alarms because nurses did not change the physiological monitor parameters from the pediatric default settings until after the alarm was triggered and it was noticed that the parameters were not appropriate.

The physiological monitors are equipped with three types of audible alarms signifying the level of severity. A yellow alarm is a warning alarm that signals a vital sign outside the setting range. A red alarm, or high alert alarm, signals when a vital sign falls outside the preset threshold parameters. The third type of alarm is noted as a blue alarm, or inoperable alarm and signals when there is a connection problem with any of the sensors.

There is currently one policy at UNCH specific to managing pediatric cardiorespiratory and pulse oximetry monitoring, NURS 0460. This policy briefly outlines the nursing assessment, instructions for notifying the physician, nursing care, safety, patient and caregiver education, and documentation. This policy did not mention the management of alarm parameters or designate parameter changing authorities. It was vital for 6CH, an acute care unit with a higher nurse-to-patient ratio, to improve alarm frequency and reduce the risk of alarm fatigue to protect and advocate for patients and promote the hospital's family-centered care mission.

Tools

For this project, a spreadsheet format generated in Microsoft Excel was used to enter, store, and analyze all data used for this project. The spreadsheet included the unique patient identification number, patient age, and all outcomes noted in the next section. A draft data collection template is provided in Appendix D. The data collection template was developed specifically for this project; therefore the reliability and validity of this tool is unknown. Prior to project initiation, the data collection template was piloted by the project lead and a designated

representative on 6CH. Three patients were pre-selected and each person collected the template data individually. After the pilot, the data from each person was compared via statistical analysis to ensure template reliability and validity. No identifying information was collected about the volunteer nurse or other clinicians involved in alarm parameter orders.

For the analysis portion of this project, a Microsoft Excel macro was utilized to quantify and characterize alarm data retrieved from the physiological monitor. The macro was provided by the UNCH Patient Safety Officer and used throughout the hospital for physiological monitors alarm characterization prior to this project.

Phase One: Baseline Data Collection Plan

In this project I addressed the alarm parameter problem by collecting data to provide baseline information regarding parameter adherence problems. The data were collected by the project lead in a retrospective manner since the physiological monitors do not store patient data for an extended time after patient discharge. There were six age categories used for vital sign parameters: less than 1 month, 1-12 months, 1-3 years, 4-5 years, 6-11 years, and 12-18 years. These correspond to the default age ranges in the EHR system at the project site. All patients over the age of 18 were excluded from this project. Data collection plans called for a target enrollment of 60 patients: 10 patients per age category from the general pediatrics services PMA, PMB, and PMG. To reduce complications with the development of the intervention implementation, it was necessary to focus data collection between these three teams as there is an attending overlap and the patient diagnoses are similar in nature.

Data on a total of 54 patients were used for data collection in this project. The number of patients enrolled per age group is shown in Appendix E. For the age group, 4-5 years, only 4 patients were included because a minimal number of patients in this age group were admitted to

6CH during the data collection time. To be included, patients had to have continuous physiological monitoring for over 24 hours to capture a patient's daily fluctuations in vital signs. To ensure patient privacy and reduce data duplication, a digital log was created with the patient name, data collection date, medical record number, and a randomly assigned study identification number. The log was kept on a password encrypted flash drive in a locked cabinet within a locked room at the project site. The data collection template only contained the randomly assigned study identification numbers, but no identifying information of patients or clinicians.

Data on multiple outcomes were collected for each patient, related to three vital signs: heart rate, respiratory rate, and oxygen saturation (measured by pulse oximetry). For each vital sign, data were collected on the EHR order range, the settings entered by the nurse in the physiological monitor, the average in a 24-hour time period, and the total number of alarms in the same 24-hour time period. The EHR order and the vital sign averages were collected through chart reviews in the EHR since these data are verified by nursing. The vital sign information in the EHR flows in from the physiological monitoring system. The physiological monitor settings were collected by reviewing the settings in the main monitoring station on the unit, and the total numbers of alarms were collected by extracting alarm data from the physiological central monitoring station in the general alarm review interface. For this project, I did not differentiate between false positive alarms and true alarms for each patient since direct patient observation was not part of the study, but I did collect data on the total number of alarms per patient per vital sign. It is also important to note that there was a plan in the event of the discovery of unsafe alarm settings during data collection. The plan called for notification of the patient's primary nurse so that safety concerns could be addressed. Also, the patient would not be included in this study to reduce potential introduction of bias. Other variables collected include patient diagnosis,

age at time of collection and provider service team. The data were collected retrospectively until the target numbers of patients per age group were satisfied but not longer than 6 months.

After data collection, the project entered the data analysis phase, and the following were determined: number of alarms per vital sign per patient, whether EHR orders and physiological monitor settings matched, adherence rate, the average for each vital sign for each age group, and if this average was within the EHR default parameter settings. An analysis of current hospital policy and protocol was performed as well.

Phase Two: Interventions

After analyzing the baseline data, I applied the IHI Model for Improvement framework to analyze and develop appropriate interventions. A collection of teams were convened and presented with the resulting data before starting the Model for Improvement process. The first team included the 6CH nursing leadership group, which focused on discussing data relevance to nursing and how to improve these outcomes from a nursing standpoint. A second team was formed by the PMA/PMB attending physicians, and data collection results were presented and discussed related to alarm parameter notification settings. Lastly, a private meeting was set up with UNCH's patient safety officer to present all results and determine the pathway needed for potentially making changes within the EHR.

The teams reviewed the baseline data and brainstormed to set specific and measurable aims for an intervention, establish target outcome measures, and select potential changes that will improve the current process (IHI, n.d.). The first team, the 6CH nursing leadership team, convened to focus on just the nursing problems and developed a set of proactive interventions to be performed by the nursing staff to promote the safety of their patients and their workplace, including strong education initiatives that covered alarm configuration instructions, parameters,

and equipment guidance, with the strong utilization of cross-disciplinary teams and organizational leaders. The second team consisted of physicians that focused on interventions surrounding the appropriateness of the default orders in the EHR compared to the actual vital sign data presented to them.

After these initial steps the project entered the PDSA cycle, and I developed and deployed an intervention to address alarm parameters through education and policy reform, perform the intervention, study how it affected alarm outcomes, and then make changes accordingly (IHI, n.d.). In this project the intention was to complete the PDSA cycle through the ‘Do’ section as timing did not allow for recollecting data to compare to the baseline data collection. Appendix F summarizes Phase 2 of this project.

CHAPTER 3: RESULTS

Phase One: Collection of Alarm Parameter Adherence Data

Data analysis focused on general demographic information to demonstrate a strong association within each of the age groups and the main themes of the project: alarm parameter adherence, total number of alarms, and the average vital signs for each age group.

Demographics

To fully understand the patient population of this project, the subjects were categorized based on age distribution (Figure 1), weight as a function of age group (Figure 2), diagnoses by systems (Figure 3), and service teams by age groups (Figure 4). There was an even distribution of ages within each age group indicating that the data was not skewed towards one specific age. The weight ranges were calculated to ensure similarity within each age group, but since the total number of patients was small, the association was inconclusive. The neurological system contained the largest number of patients in this project, at 41%, with the most common diagnosis as ‘seizures.’ This is not surprising as 6CH contains four epilepsy monitoring unit rooms and these patients are typically required to wear continuous physiological monitoring. Service teams PMA and PMB had similar total patients used for this study, with more patients on the PMB service. The PMG service had significantly fewer patients; this is attributed to the addition of this group as inclusion criteria midway through data collection to attempt to recruit patients in lower populated age groups.

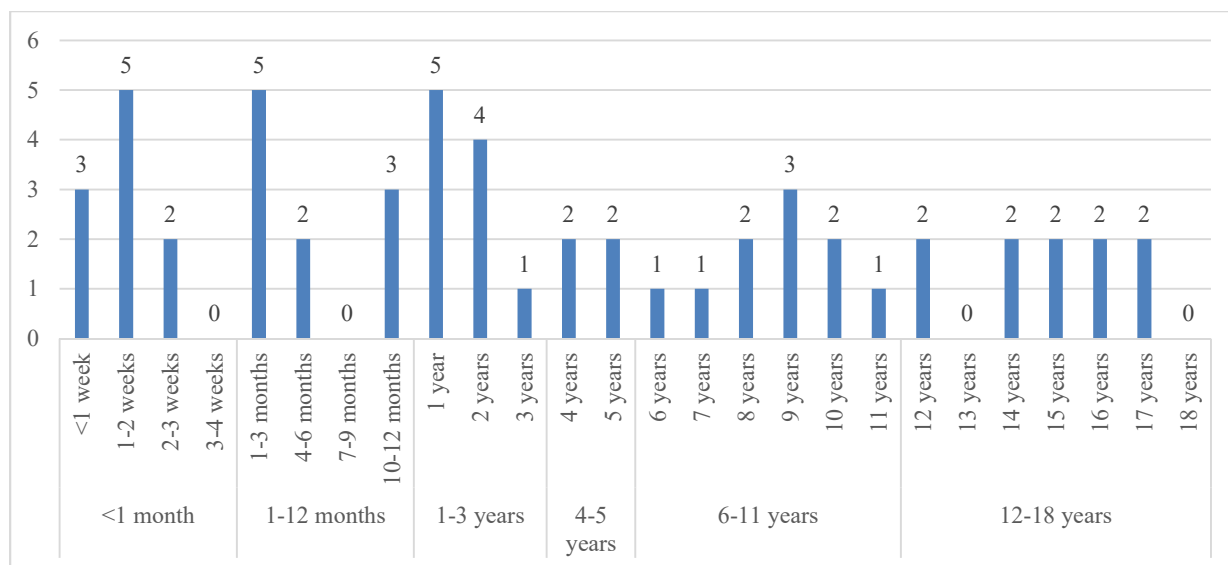


Figure 1. Age distribution within the 6 age groups. Numbers represent total patients of corresponding age.

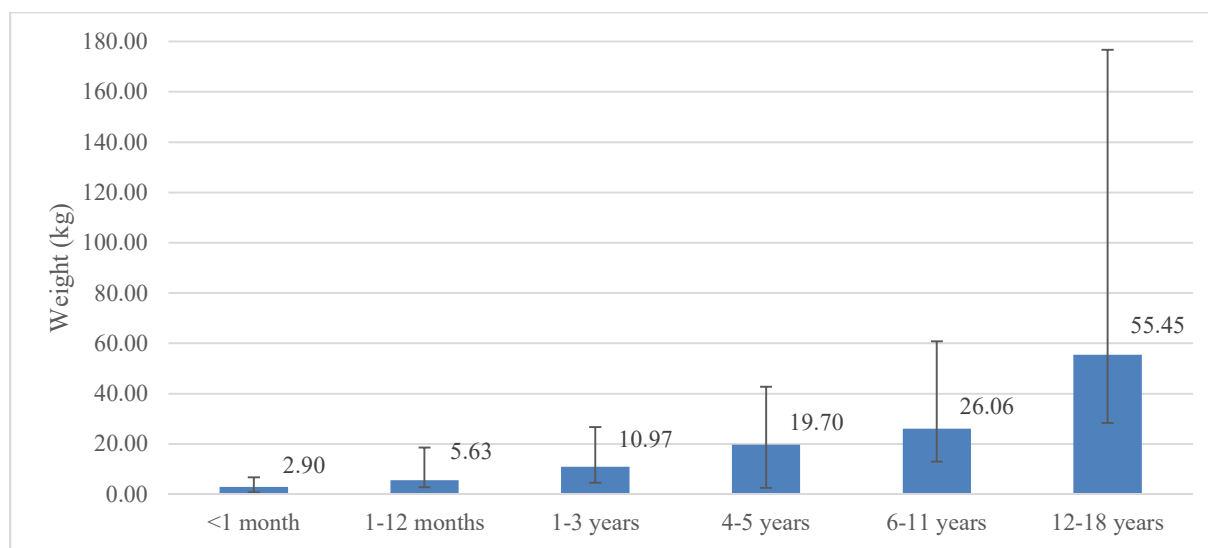


Figure 2. Average weight for each age group. Error bars represent the minimum and maximum weight recorded for each age group.

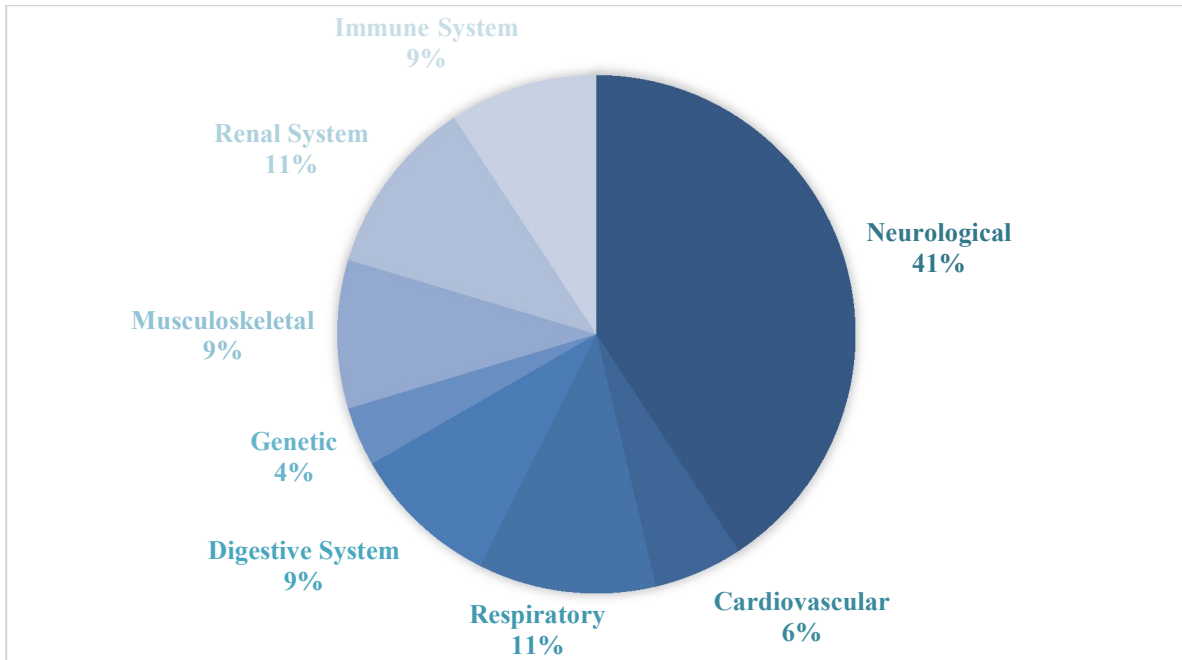


Figure 3. Diagnoses representation for project sample.

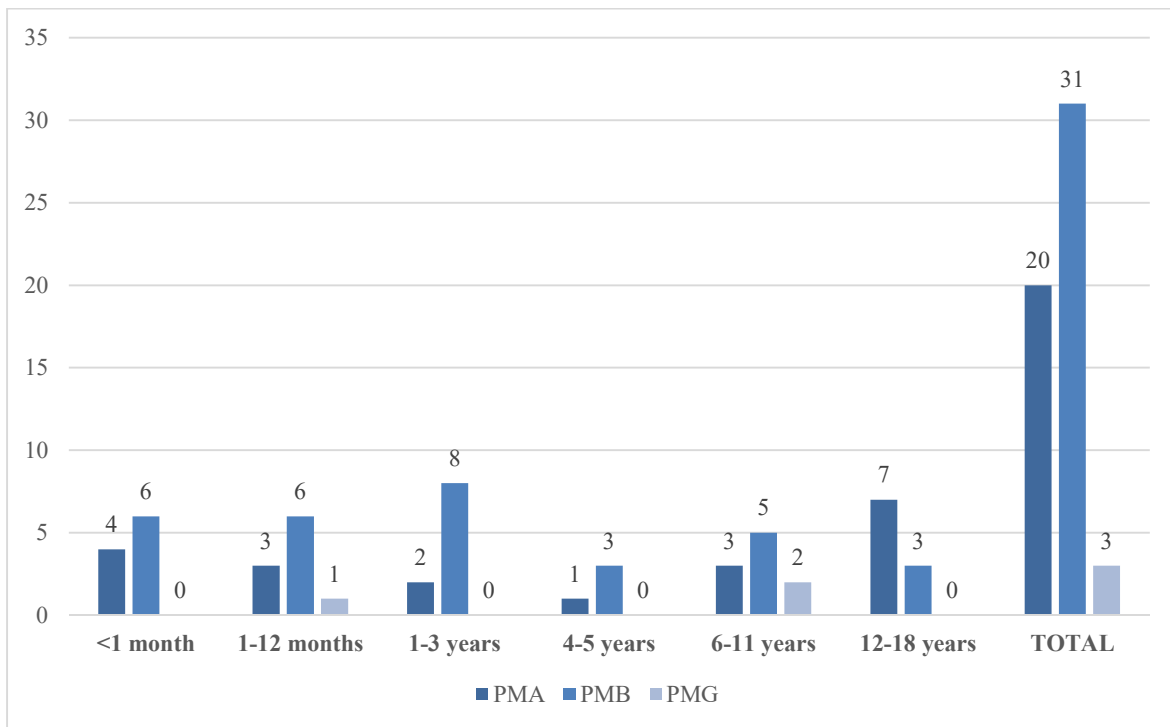


Figure 4. Total number of patients per medical team displayed as separate age groups and as a total.

Alarm Parameter Results

To assess the status of alarm parameter adherence on 6CH, the physiological monitor settings were compared to the EHR orders and determined if the parameters matched. Figure 5 illustrates the percentage of patients with correct physiological monitor settings. Only 2% of patients had the correct physiological monitor settings for the entire heart rate range, with 0% for respiratory rate and 65% for pulse oximetry. The heart rate maximums on the physiological monitors were almost always set higher than the default EHR orders for each age group.

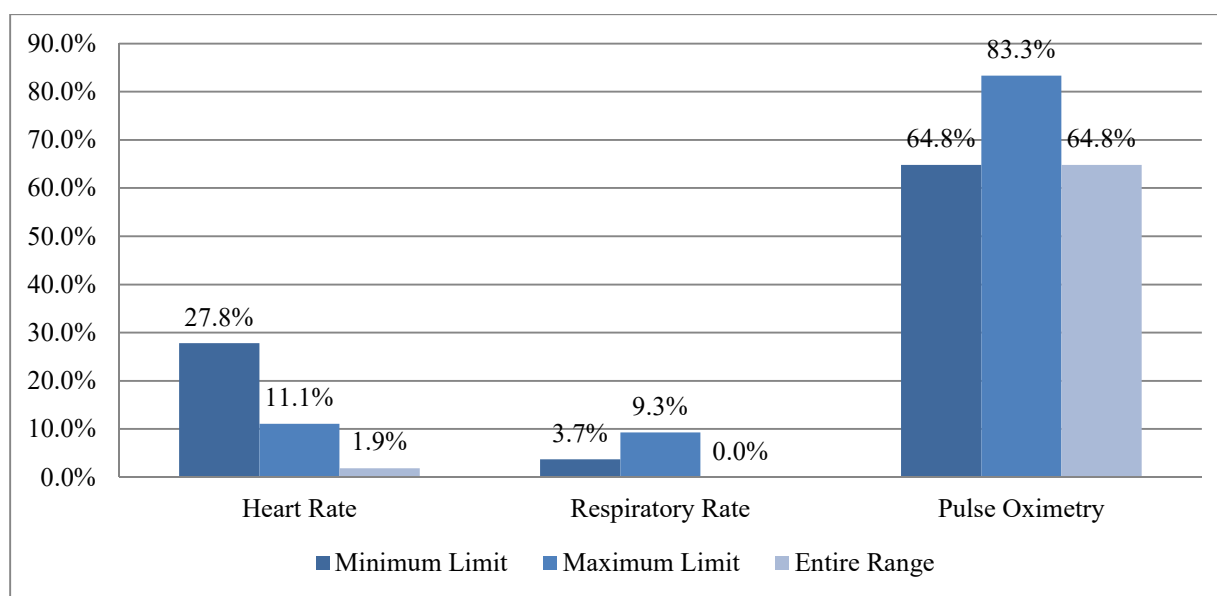


Figure 5. Percentage of patients with matching EHR orders and physiological monitor settings for heart rate, respiratory rate, and pulse oximetry. Minimum and maximum limits are the lowest and highest settings respectively. Entire range indicates all parameter settings correlate.

Next, the percentage of patients with customized orders was examined—meaning that the EHR order for the patient had been altered from the default setting specific to the patient. Figure 6 demonstrates that few patients had customized orders with the highest customization among the minimum heart rate orders at 24.1%. It is apparent that even if there were customized EHR orders, the physiological monitor settings still did not match. With customized parameters the

physiological monitor settings were still set wider, with the exception of the pulse oximetry in which the default is 92%. Table 1 breaks down the customization percentages.

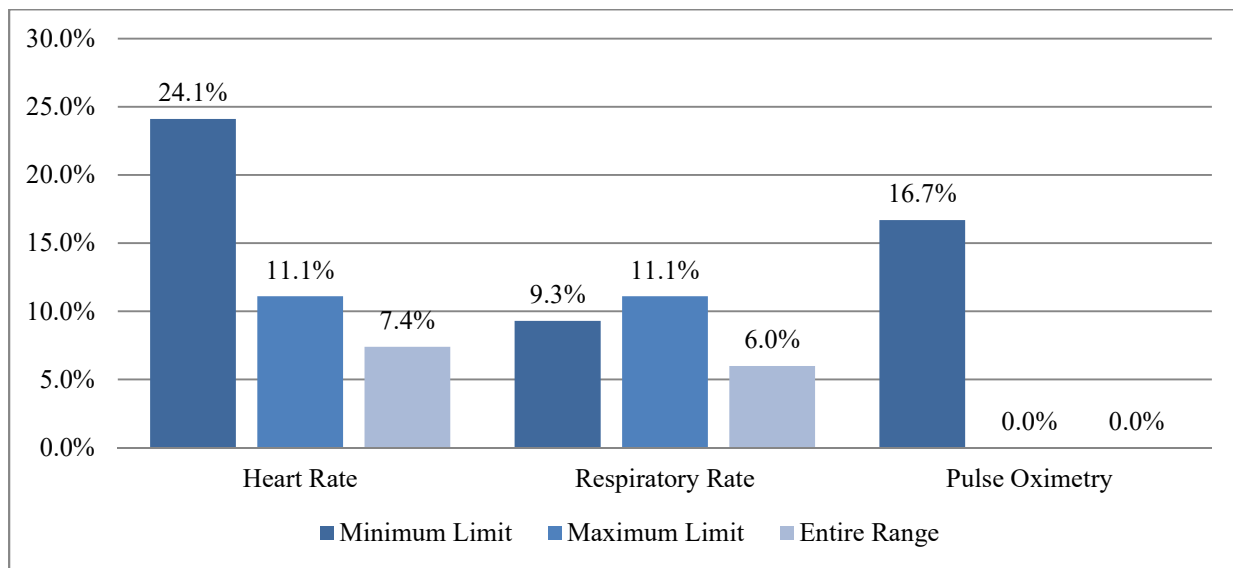


Figure 6. Percentage of patients with customized orders—meaning that the EHR order for the patient had been altered from the default setting specific for the patient.

Table 1

Customization Percentage

	Heart Rate			Respiratory Rate			Pulse Oximetry		
	Min	Max	Entire Range	Min	Max	Entire Range	Min	Max	Entire Range
Customized EHR Orders	13	6	4	5	6	3	9	0	0
Customized and Matching	3	1	1	2	0	0	1	0	0
Percentage	23%	17%	25%	40%	0%	0%	11%	0%	0%

Note. This table examines the number of patients with customized orders and how many of those patients had the correct physiological monitor settings per EHR orders.

Alarm Results

Yellow Alarms

The yellow alarms, or warning alarms, were observed to be the most common alarms in this project. There was approximately 7,200 total yellow alarms, which represents approximately

6 alarms per patient per hour. Knowing that there are typically 4 patients per nurse on 6CH that totals to about 288 alarms per nurse per 12 hour shift assuming all 4 patients are on physiological monitoring. Figure 7 breaks down the total number of yellow alarms per vital sign and low or high alarm.

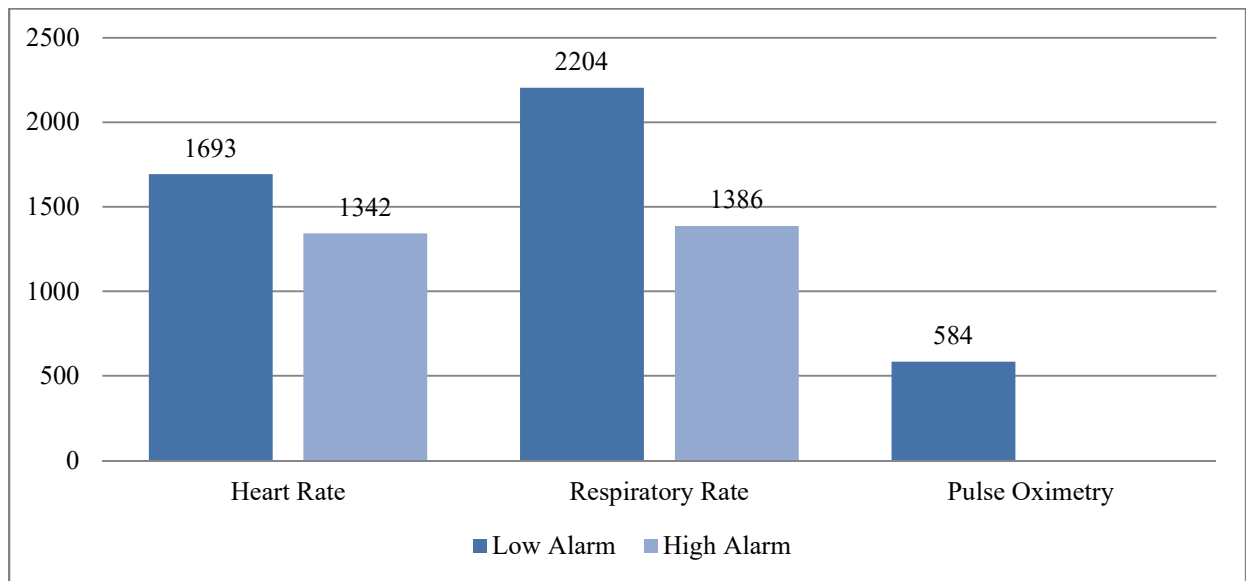


Figure 7. Total number of yellow alarms.

For trending purposes, the total number of yellow alarms was stratified by age groups (Appendix G). There were more pulse oximetry alarms in the younger age groups. Greater than 85% of heart rate alarms were above the higher physiological monitor setting for the less than 1 month to 11 year old age groups. Approximately 91% of heart rate alarms for the 12-18 year old age group were below the lower physiological monitor setting. The majority of all respiratory rate alarms were triggered as below the physiological monitor settings, which was the category with the most yellow alarms.

Red Alarms

Pulse oximeter alarms were the most frequent red alarms, where the younger age groups generated the largest number. Red alarms can be generated if the signal is weak and the patient is

moving—this project did not differentiate a true positive from a false positive alarm. Figure 8 illustrates the red alarm distribution. It was also determined that 20% of all red alarms were from patients with customized EHR orders (Table 2). Further information on the number of red alarms per age group is located in Appendix H.

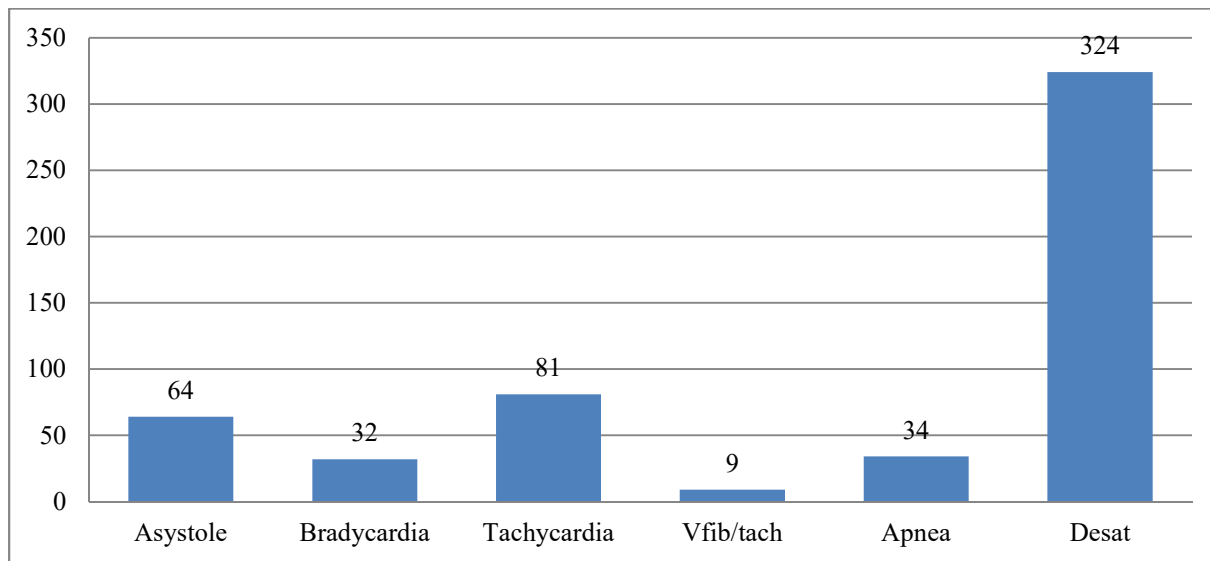


Figure 8. Total number of red alarms per alarm category.

Table 2

Comparison of Red Alarm Generation between All Patients and Patients with Customized Orders

	HR				RR	SpO2	Total
	Asystole	Brady	Tachy	Vfib/Tach	Apnea	Desat	
Customized Patient Alarms	9	18	4	1	1	78	111
All Patient Alarms	64	32	81	9	34	324	544
Percentage							20%

Note. The patients included in the customized patient alarms category must have had customized EHR orders. The alarms coinciding with these patients were counted as follows: minimum heart rate included asystole and bradycardia alarms, maximum heart rate included tachycardia and ventricular fibrillation/tachycardia, respiratory rate included apnea, and pulse oximetry included desaturation alarms. The percentage was taken from the total number of red alarms from customized patients and the total number of red alarms.

Inoperable Alarms

The third type of alarm assessed in this project were the inoperable alarms. There were three alarm categories within this type of alarm: battery, leads off, and SpO2. For clarification purposes the SpO2 alarm meant that the signal was poor. Table 3 represents the alarm data collected for inoperable alarms. It was deduced that 709 of the 733 inoperable alarms are attributed to the heart rate monitor leads falling off the patient due to decreased adhesive or patient pulling them off.

Table 3

Total Number of Inoperable Alarms by Age Group and Type of Alarm

	Battery	Leads Off	SpO2	Total
<1 month	0	90	0	90
1-12 months	0	65	0	65
1-3 years	0	122	0	122
4-5 years	0	45	0	45
6-11 years	0	155	0	155
12-18 years	9	232	15	256
Total	9	709	15	733

Note. The total number of inoperable alarms were calculated for each age group and for each type of alarm.

Vital Signs Results

The third component of data analysis for this project assessed the appropriateness of the default EHR orders for each of the vital signs, compared to the actual measured averages for each age group. Figure 9 characterizes the average minimum and maximum for each vital sign and its relation to the default EHR order per age group. The average maximum heart rate was greater than the EHR default maximum orders for four of the six age groups (1-12 months, 1-3 years, 4-5 years, and 6-11 years). All of the age groups had average pulse oximetry readings within the EHR default parameters. For the respiratory rate, the average minimum was less than

the EHR default orders for all age groups and the average maximum was greater than the EHR default orders for three of the age groups (<1 month, 1-3 years, and 6-11 years).

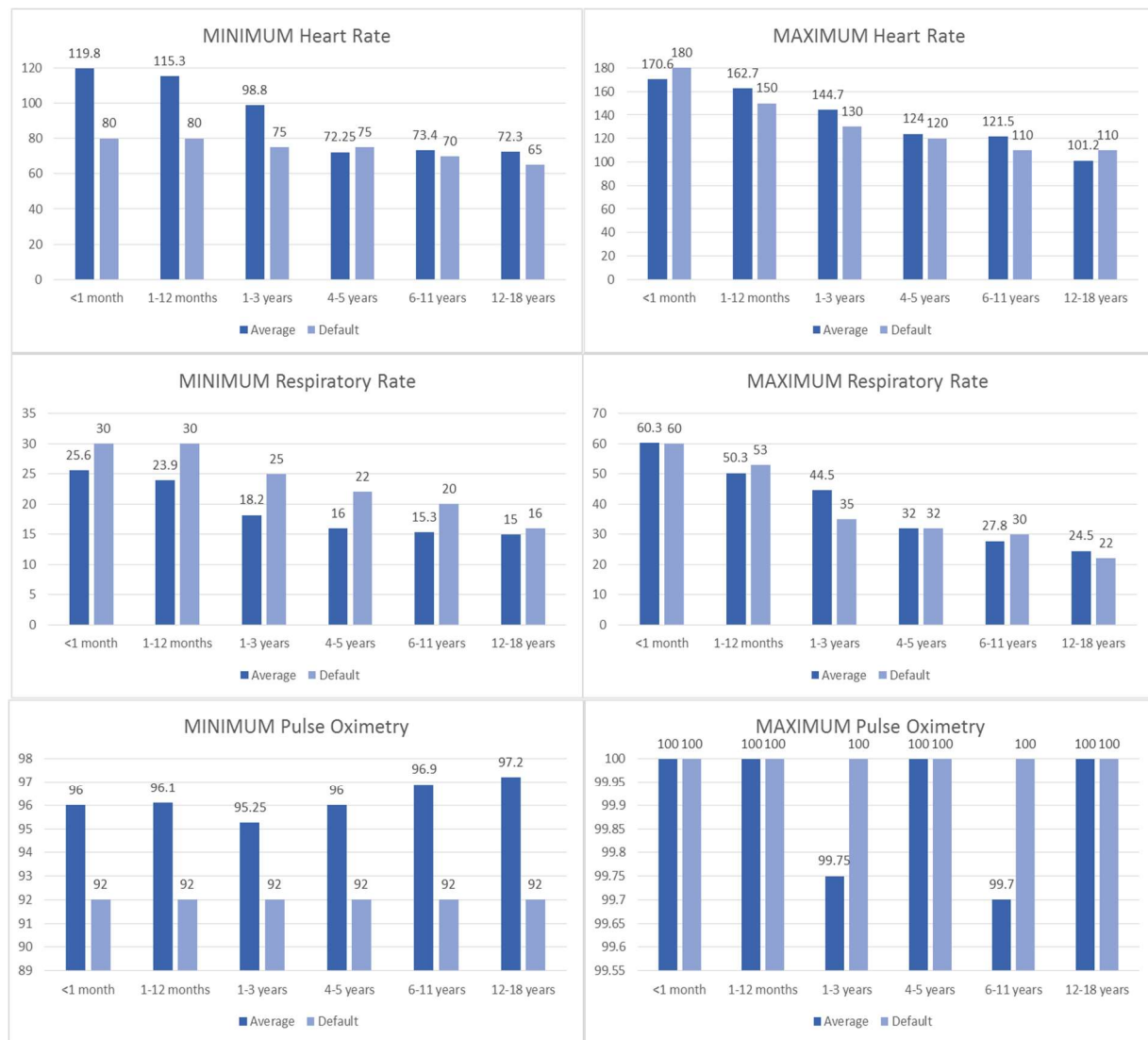


Figure 9. Compilation of the average minimum and maximum vital sign compared to the default EHR order for each age group. Appropriate default orders are justified when the average minimum is higher than the default order and the average maximum is less than the default order.

Phase One: Summary

- Only 2% of patients had their entire physiological monitor alarm parameter settings for heart rate correlate with their EHR order, with 0% for respiratory rate and 65% for pulse oximetry.

- Few patients had customized EHR parameter orders.
- Even when patients had customized EHR parameter orders, the physiological monitor settings did not match, indicating a nursing issue.
- The average maximum heart rate fell outside the EHR default orders for age groups 1-12 months, 1-3 years, 4-5 years, and 6-11 years.
- The average minimum respiratory rate fell outside the EHR default orders for all age groups.
- Younger age groups generated the most pulse oximetry red alarms, which were the main source for the red alarms.
- 20% of all red alarms were from patients with customized EHR alarm parameter orders.
- The yellow alarms were the largest source of alarms, with the majority of all yellow alarms triggered from low respiratory rates.
- Greater than 85% of heart rate alarms were above the high physiological monitor settings for ages less than 1 month to 11 years old.
- 91% of heart rate alarms for 12-18 year olds were below the low physiological monitor settings.
- The majority of inoperative alarms were due to monitor leads not sticking to the patient's skin.

The abundant information derived from the Phase 1 data collection informed the intervention in Phase 2 of the project.

Phase Two: Development and Deployment of Alarm Parameter Adherence Educational Intervention

The intervention implemented in this project was focused on education for improving alarm parameter adherence by nursing staff on 6CH. The education emphasized the importance of customizing alarm parameters for each pediatric patient, and ensuring correct parameters are programmed in the monitoring system.

To accommodate most learning styles, visual, verbal, and physical education was developed and shared with the nursing staff. An email, specifically focused on alarm parameter adherences, was developed and sent to nursing staff. This included the alarm parameter responsibilities for nurses and the expected alarm parameter nursing workflow stated in the UNCH nursing policy (Appendix I). This same information was included in the 6CH weekly update. To target visual learners, an educational poster was displayed on the unit for over 1 month that included alarm parameter adherence results from this project, steps to change parameters in the physiological monitors in picture form, and expected workflow (Appendix J). A reminder card was placed on the top right corner of every computer on the unit, shown in Appendix K, to serve as a cue to nurses to check parameters while they are charting and checking orders. Lastly, physical and verbal learners were provided with one-on-one in-services, with the goal of educating 75% of nursing staff. Appendix L displays the prompts for the in-service training, which includes a combination of teach-back method along with hands-on manipulation of the physiological monitors.

It was determined that approximately 75% of nurses, received the one-on-one in-service training. All nursing staff, including assistive personnel, received the education delivered by email and/or weekly update. It was unknown how many people read the education piece. During the provider team meeting, there were approximately 10 physicians and 3 nurse practitioners in attendance, which comprises at least half of the attending faculty and all of the nurse practitioners in pediatrics for the main pediatric medical teams.

Modifications of nursing policy and notification settings within EHR remain in process and are expected to continue beyond this project.

The Synergy Model for Patient Care and Alarm Fatigue

The SMPC guided the alarm management approach for this project, with the goal of preventing alarm fatigue by aligning nursing competencies, patient characteristic customization, and interdisciplinary communication. The project intervention incorporated all eight nursing competencies; eight patient characteristics of the SMPC; and evaluation of patient, nursing, and system outcomes. By using the SMPC framework, this intervention initiated communication among pediatric clinicians focused on the current state of the physiological monitoring system and on developing appropriate and customizable alarm parameter configuration practices.

A comprehensive approach using the SMPC ensures nurses are provided with adequate training and knowledge to properly grasp all scenarios and make clinical judgments and inquiries based on experience. For example, the alarm management approach provided situational-based guidelines prompting nurses to evaluate patient-specific care for alarm parameter appropriateness. The goal was to integrate all patient care disciplines while enhancing communication and individualizing patient care. The approach synergized all nursing competencies and required strong emphases on advocacy, collaboration, systems thinking, and response to diversity. The approach required daily interdisciplinary communication (collaboration among clinicians) and addressed appropriate vital sign parameters and need for physiological monitors (advocacy/clinical inquiry and judgment) for applicable patients (diversity).

CHAPTER 4: DISCUSSION

I found a strong lack of alarm parameter adherence on 6CH among the nursing staff. The alarm parameters entered into the physiological monitors were often inconsistent with the EHR orders for each patient, and as a result, the patients alarmed excessively or had wider alarm parameter settings than what they were ordered for. False alarms creates noisy environments that nursing staff learns to ignore or work-around, contributing to alarm fatigue. As a result, wider alarm parameters were used, which can cause a delay or missed signs of real distress in patients. The evidence gathered during this project supports the strong need for nursing education and a change in culture surrounding alarm parameter adherence.

Another nursing issue that was not the focus of this project but requires discussion, was the large number of inoperable alarms. The greatest alarm within this category was that the leads were off the patient. These alarms are highly preventable by nursing staff. After reviewing the initial data, the project lead suggested this be a topic of education for a group of new graduate nurses to perform on the unit—the education was not implemented until after data collection for the project was over to ensure that it would not influence results.

TJC strongly suggests that patient customization is a vital component of managing patient cardiorespiratory alarms. This project highlighted that even though there are multiple age groups within acute pediatric care, customization still needs to be performed for each child, meaning that the default orders in the EHR should serve as a general guide for the patient based on age. Customization requires the nursing staff and medical team to work closely together to ensure that the patient's orders reflect the patient's physiological status. It is nursing's responsibility to

notify the providers when a patient alarms outside of the default orders, and it is the physician's responsibility to promptly change the orders within the EHR to avoid repeat pages about the same topic. The project demonstrated fewer red alarms were generated from those patients with customized orders, but customization did not entirely eliminate alarms. This indicates that if all of the pediatric patients had customized alarm parameters, the number of false alarms could be reduced drastically.

There was a strong association in this project between the sizable total number of low respiratory rate alarms and the average minimum respiratory rate being lower than the EHR default alarm settings. This indicated that if the EHR default settings were lowered to resemble actual patient respiratory rates, there would be fewer generated yellow alarms for respiratory rate. The medical teams were presented with this option, and there are initial in-process steps to update the EHR default alarm settings for respiratory rate for all age groups.

Meeting patients' safety needs is necessary to obtain positive clinical outcomes and must be addressed in any intervention. The alarm management approach recommended in this project potentially ensures patients' vital sign parameters are safe. It allowed a level of adaptability, with proper team collaboration to account for resiliency, stability, complexity, and predictability of the patient and its clinical signs and symptoms. By promoting flexibility, it allows the team to customize the patient's alarm system, therefore decreasing alarm frequency.

Synergy of nursing competencies, patient characteristics, and system factors provide the ability to develop an all-encompassing alarm management approach that customizes alarm parameters for patients. An intervention aimed to reduce alarm fatigue utilizing other theories does not promise the same interaction among the three sectors regarding alarm management. Other theories prove difficult to align patient characteristics to nurse competencies and training,

and there is a breakdown in the relationship among patient customization, how nursing practices, and resulted outcomes. A framework that holds nurses accountable for their practices ensures competent patient care and synergism throughout the health care system. The development of a standardized alarm management approach based on the AACN's SMPC guarantees a comprehensive collaborative intervention necessary to target alarm fatigue.

The inter-disciplinary approach I introduced in my educational intervention, though challenging, opened communication regarding alarm parameters among the clinicians on 6CH. Overall, nursing staff were receptive to education since they are impacted by the physiological alarms the most. Many staff often stated that they knew how to change the parameters in the monitoring system but hesitated when asked to perform it during the in-service. This reinforced the idea that not many nurses are persistent in adhering to alarm parameter policy. My presentation to the attending physicians generated conversation, mostly regarding the number of alarms per nurse as they are not as exposed to alarms. The physicians also discussed the appropriateness of the default alarm parameters compared to the actual vital signs information at length amongst each other. It was interesting that during this discussion they were all in agreement that some things needed to be changed but not one person decided to take the lead in attempting to change it. This was the greatest challenge of this project—to determine the motivation for change regarding alarm parameters adherence among the nurses and providers. For each group, there needs to be designated champions to push for a change in culture or practices.

CHAPTER 5: LIMITATIONS

Approximately two-thirds of the way through data collection it was noticed that one of the age groups, 4-5 year olds, was not populated like the other age groups. Only 4 patients were included for data collection due to time constraints. An admission report for 6CH was obtained from NC Children's Hospital administration to look at specific age demographics. As suspected, between May 18, 2016 (data collection start date) and July 12, 2016 (data collection two-thirds point), only 5% of all total qualified admissions were patients aged 4-5 years old. Other age groups ranged from 12% to 28%. The report summary related specifically to this project is located in Appendix L.

As a result of smaller samples than originally anticipated, the total sample was reduced from 20 patients per age group to 10 patients per age group to reduce a wider gap between data collected for each age group. Also, the PMG service team was added to provide a wider population for data collection.

Time also was a limitation for this project as there was a 2 month gap in data collection due to lack of access to data by the principal investigator. Also, data collection needed to be completed before respiratory illness season began to prevent a skew in the results.

It must be noted that within this project it was noticed that there was an overlap in the EHR default age groups. These age groups are listed in the EHR as '1-3 years' and '3-5 years' but for this study it was designated as '1-3 years' and '4-5 years.' This inconsistency within the EHR can cause confusion for providers entering orders as they have two alarm parameter default order sets that they could use.

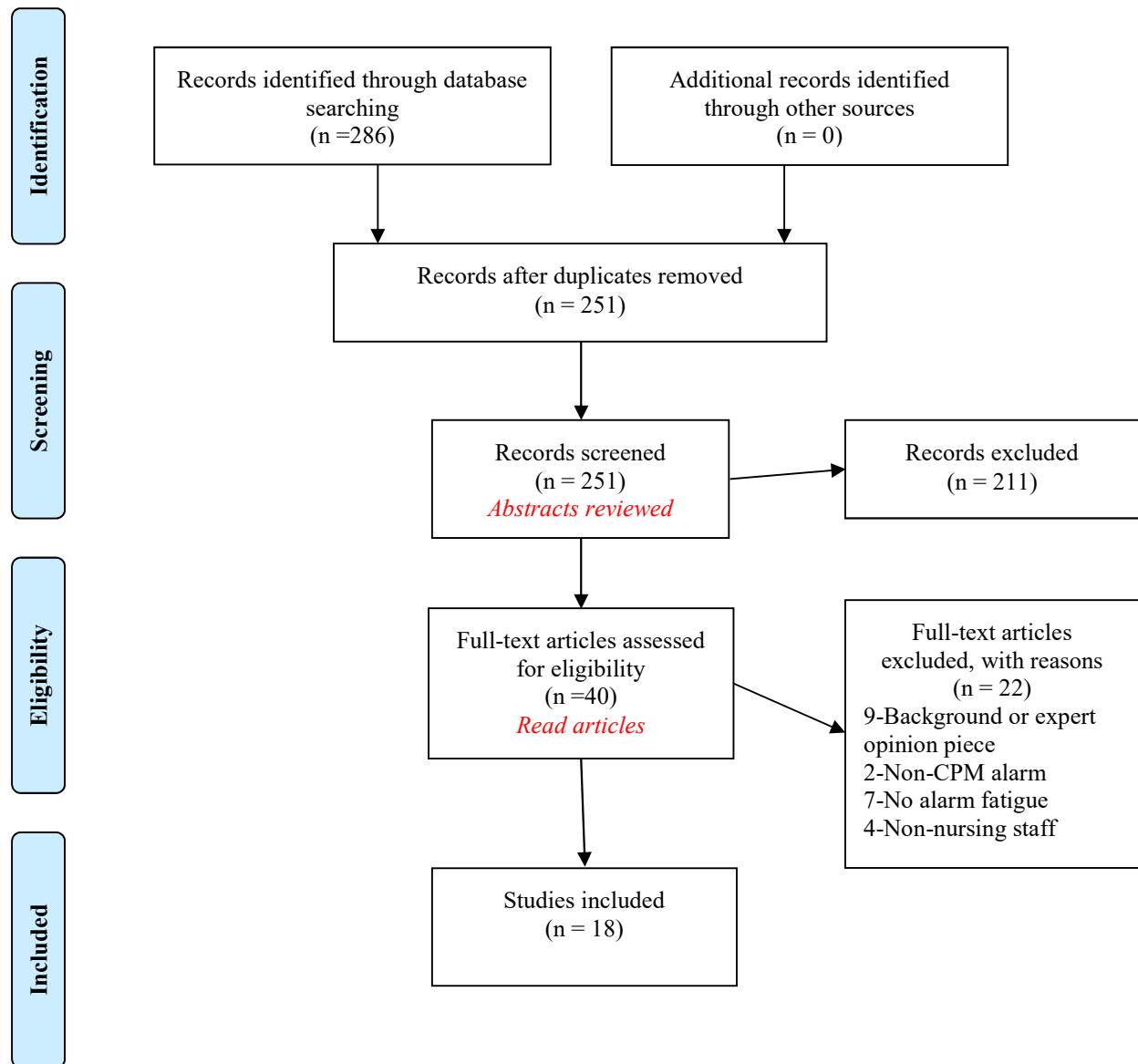
CHAPTER 6: CONCLUSION

In this DNP project, I demonstrated that a standardized alarm management approach focused on alarm parameters can be adopted by nurses and physicians on an inpatient pediatric unit with a large volume of false alarms. The approach has the potential to prevent alarm fatigue among hospital staff and reduce the risk for patient-related sentinel events. In the first phase of this project, I collected data on alarm parameter compliance on 54 patients on 6CH. I found that the minimum respiratory rate yellow alarm was the largest alarm contributor, which coincides with the EHR default parameter orders for the minimum respiratory rate as too high for the pediatric patient population. I also found that few patients had their entire range for any vital signs programmed correctly in the monitoring system, indicating a clear nursing workflow breakdown.

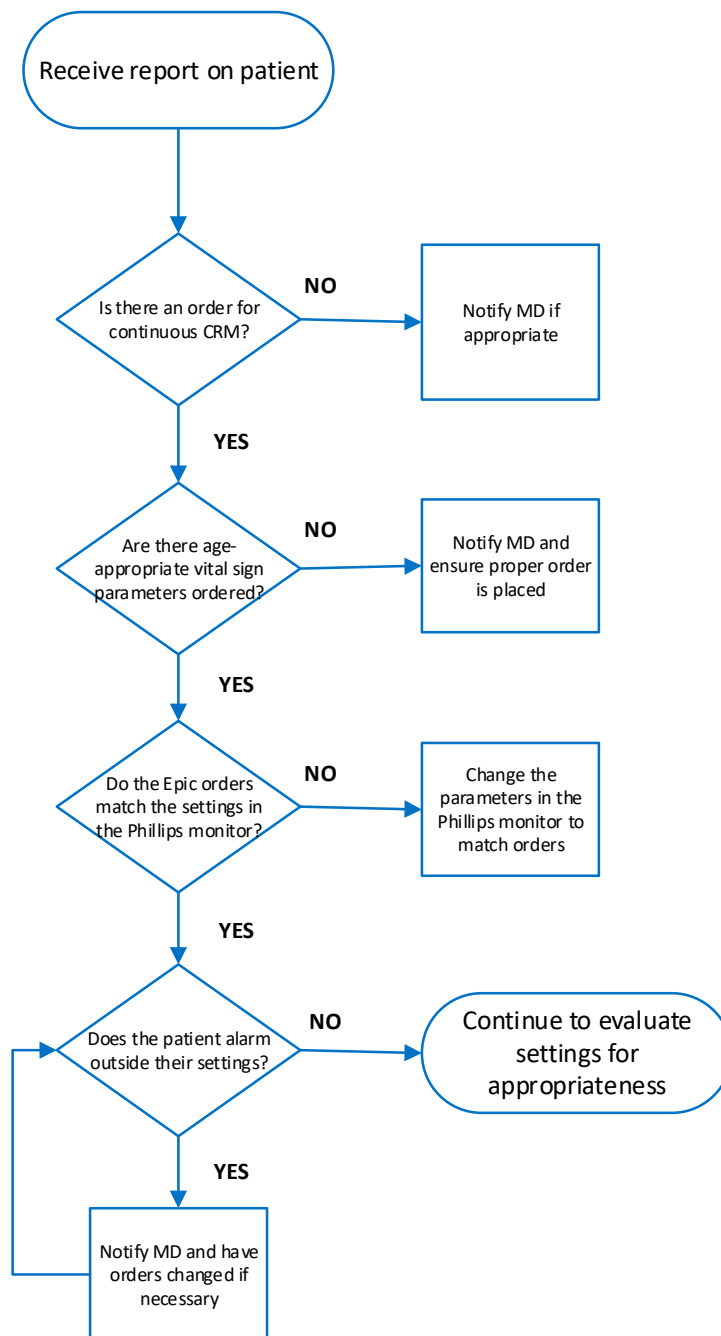
In the second phase of this project, I designed and delivered the intervention, which included a set of proactive educational interventions addressing alarm parameter adherence and patient customization, with the active involvement of inter-disciplinary teams and organizational leadership. A meaningful alarm management approach that incorporates these interventions naturally reflects the multi-faceted problem of alarm fatigue.

As a result of this project, it is clear that evidence-based data should be used to change default alarm parameters in the EHR with the use of evidence-based data. Future research is needed on the effectiveness of heavy educational programs targeting alarm parameter adherence, such as the program performed in this project.

APPENDIX A: PRISMA 2009 FLOW DIAGRAM OF LITERATURE SEARCH



APPENDIX B: EXPECTED ALARM PARAMETER NURSING WORKFLOW



*CRM: cardiorespiratory monitoring

**MD: medical doctor

**APPENDIX C: EHR AND PHYSIOLOGICAL MONITOR DEFAULT ALARM
PARAMETERS**

<i>EHR Age-based Default Call Parameter Order Sets</i>			
<u>Age</u>	<u>Heart Rate (bpm)</u>	<u>Respiratory Rate (breath/min)</u>	<u>Pulse Oximeter</u>
< 1 month	<80 or >180	<30 or >60	<92%
1 month-12 months	<80 or >150	<30 or >53	<92%
1 year-3 years	<75 or >130	<25 or >35	<92%
4 years-5 years	<75 or >120	<22 or >32	<92%
6 years-11 years	<70 or >110	<25 or >35	<92%
12 years-18 years	<65 or >110	<16 or >22	<92%

<i>Physiological Monitor Pediatric (1 day-18 years old) Default Alarm Parameters</i>			
	<u>Heart Rate</u>	<u>Respiratory Rate</u>	<u>Pulse Oximeter</u>
Range*	80-180 bpm	16-60 breaths/min	92-100%
Threshold**	70-200 bpm	20 seconds	88-100%
*Yellow alarm (warning alarm) goes off if outside of range **Red alarm (high alert alarm) goes off if outside of threshold			

APPENDIX D: PROJECT DATA COLLECTION TOOL TEMPLATE

Patient Demographics						
Patient ID Number	Age	Diagnosis	Service Team	Weight	Start Date/Time	Stop Date/Time
patient 1						
patient ...						
patient 60						

Heart Rate					
Patient ID Number	Epic Range	Philips Range	Patient Average	Yellow Alarms	Red Alarms
patient 1					
patient ...					
patient 60					

Respiratory Rate					
Patient ID Number	Epic Range	Philips Range	Patient Average	Yellow Alarms	Red Alarms
patient 1					
patient ...					
patient 60					

Pule Oximetry					
Patient ID Number	Epic Range	Philips Range	Patient Average	Yellow Alarms	Red Alarms
patient 1					
patient ...					
patient 60					

Technical Alarms	
Patient ID Number	Total Number
patient 1	
patient ...	
patient 60	

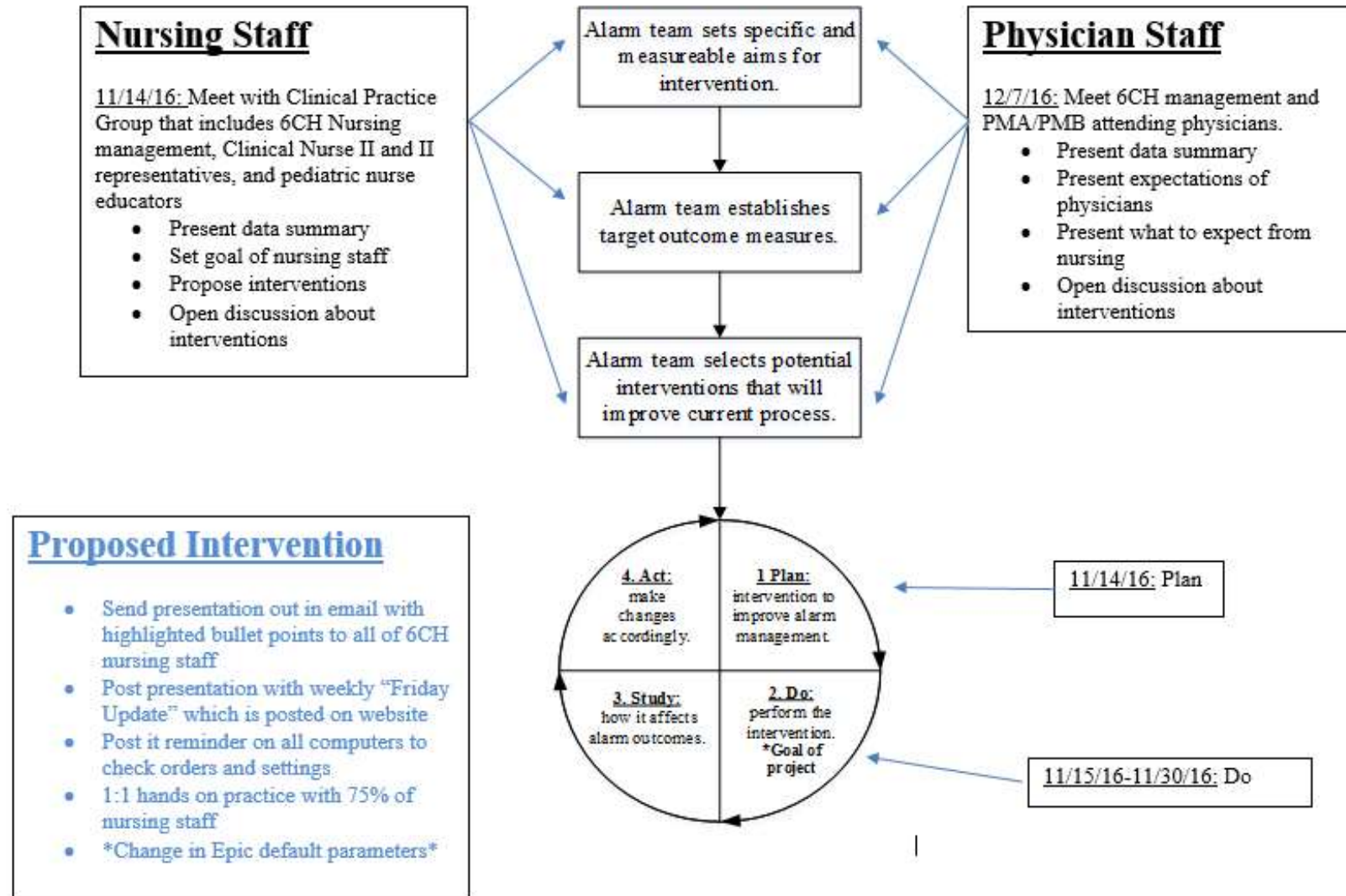
APPENDIX E: 6CH DEMOGRAPHIC REPORT

Total Potential Patients Admitted to 6CH on PMA, PMB, and PMG Services from 5/18/16-7/12/16

	May	June	July	Total	Percentage of Total Qualified	Total Study Patients	Percentage of Total Study Patients
<1 month	6	13	5	24	12%	10	20%
1-12 months	12	27	5	44	22%	10	20%
1-3 years	6	23	2	31	16%	10	20%
4-5 years	5	4	1	10	5%	3	6%
6-11 years	8	19	7	34	17%	8	16%
12-18 years	17	32	7	56	28%	10	20%
TOTAL	54	118	27	199		51	

Note. The numbers provided under the May, June, July, and total column are the total number of potential patients admitted under the designated service and dates and does not include other inclusion criteria. The percentage of total qualified calculates the percent per age group that could potentially be included in the study. The total study patients is the number of patients included in the project by July 12, 2016, and the percentage is the percent of patients per age group included in the project.

APPENDIX F: PHASE 2 ANALYSIS PLAN FLOW CHART



Adapted from "How to Improve." By Institute for Healthcare Improvement, n.d.

APPENDIX G: YELLOW ALARM BREAKDOWN

Number of Yellow Alarms Broken Down by Type of Alarm and Age Groups

Age Group	HR			RR			SpO2
	Low	High	Total	Low	High	Total	Total
<1 month	0	320	320	208	199	407	209
1-12 months	4	215	219	459	1005	1464	140
1-3 years	20	105	125	664	116	780	66
4-5 years	873	0	873	213	1	214	24
6-11 years	255	647	902	436	55	491	76
12-18 years	541	55	596	224	10	234	69
Total	3035			3590			584

Note. Representation of yellow alarm counts and totals. Pulse Oximetry only has low alarms since the highest reading is 100% and within normal limits; therefore it is indicated as ‘total.’

Percentages of Yellow Alarms per Age Group

Age Group	HR		RR	
	Low	High	Low	High
<1 month	0%	100%	51%	49%
1-12 months	2%	98%	31%	69%
1-3 years	16%	84%	85%	15%
4-5 years	100%	0%	100%	0%
6-11 years	28%	72%	89%	11%
12-18 years	91%	9%	96%	4%

Note. Percentages calculated by using numbers from the above table. The highlighted numbers represent the majority of alarms for each age group for heart rate and respiratory rate.

APPENDIX H: RED ALARM DATA BY AGE GROUPS

Number of Red Alarms Broken Down by Type of Alarm and Age Groups

	HR				RR	SpO2	Total
	Asystole	Brady	Tachy	Vfib/Tach	Apnea	Desat	
<1 month	19	0	27	6	2	122	176
1-12 months	26	0	28	1	3	109	167
1-3 years	11	0	5	1	5	30	52
4-5 years	0	1	1	0	1	9	12
6-11 years	1	18	13	0	7	33	72
12-18 years	7	13	7	1	16	21	65
Total	64	32	81	9	34	324	544

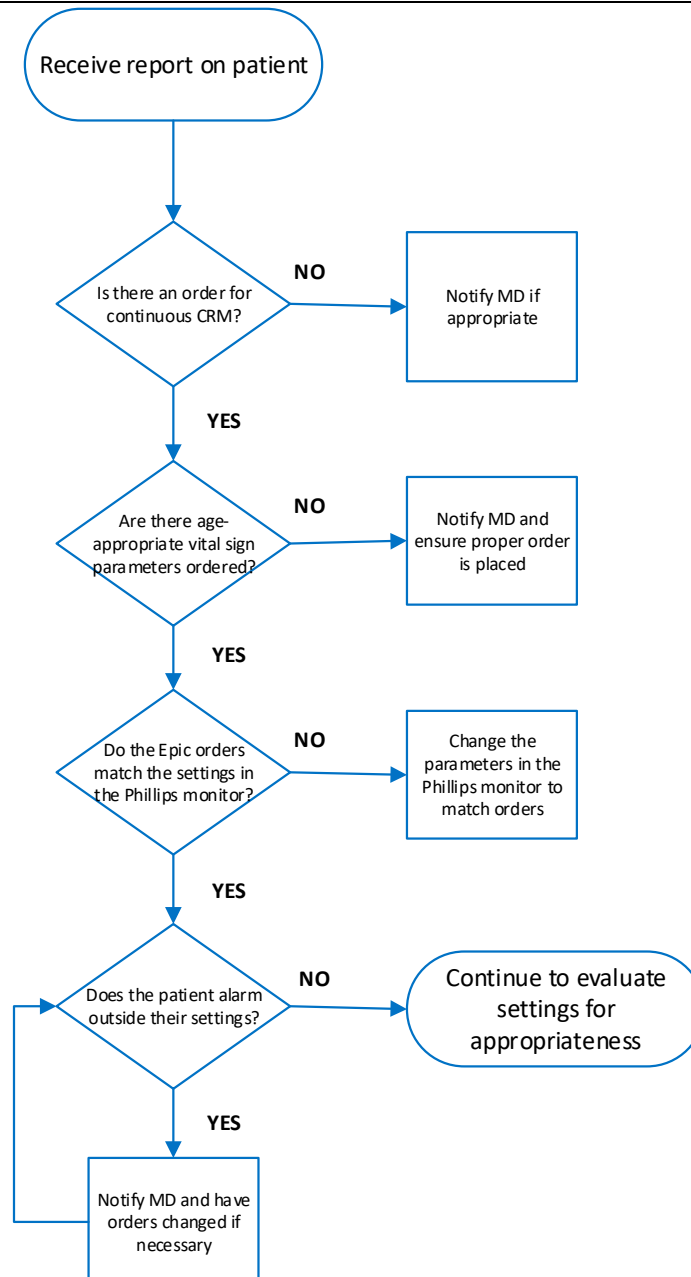
Note. Definitions of the above categories are as follows: ‘brady’ stands for bradycardia, ‘tachy’ stands for tachycardia, ‘vfib/tach’ stands for ventricular fibrillation and tachycardia, and ‘desat’ stands for desaturation. The total number per age group and per category were calculated.

APPENDIX I: EDUCATION SENT TO STAFF BY EMAIL AND ON WEBSITE

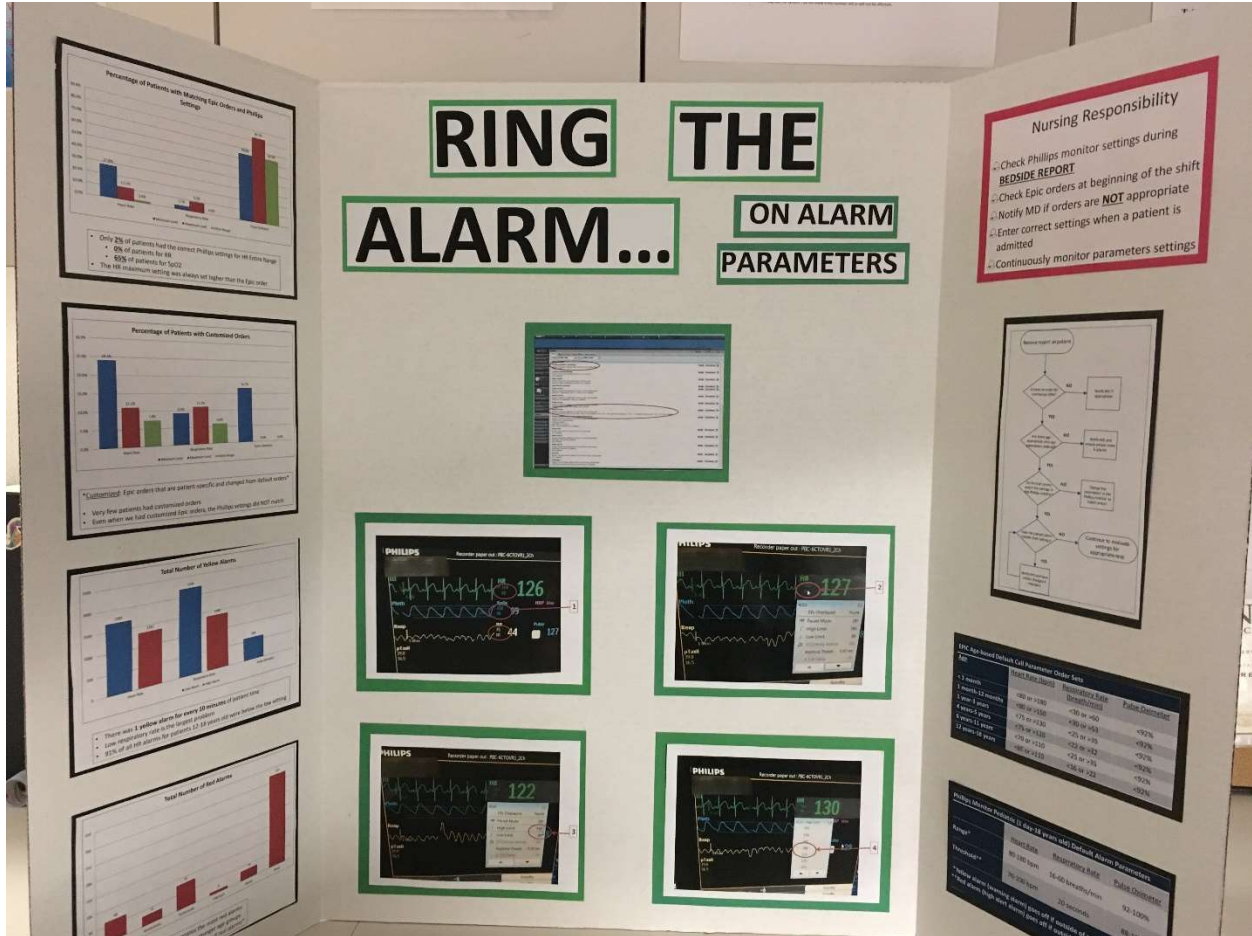
NURSING ALARM PARAMETER RESPONSIBILITIES

- 🔔 Check Phillips monitor settings during **BEDSIDE REPORT**
 - 🔔 Check Epic orders at beginning of the shift
 - 🔔 Notify MD if orders are NOT appropriate
 - 🔔 Enter correct settings when a patient is admitted
 - 🔔 Continuously monitor parameters settings

EXPECTED ALARM PARAMETER NURSING WORKFLOW-Nursing Policy 0460



APPENDIX J: EDUCATIONAL POSTER



APPENDIX K: COMPUTER REMINDER CARD



APPENDIX L: INSERVICE TRAINING GUIDE

RING THE ALARM ON ALARM PARAMETERS IN-SERVICE

- Demonstrate how to change parameters on central monitor
- Explain what yellow and red alarms are
- Return demonstration: program these settings:
 - Heart Rate: 60-100
 - Respiratory Rate: 14-25
 - Pulse Oximetry: 90-100
- Verbal Quiz:
 - When are you supposed to check call parameters?
 - When do you change measurements in the physiological monitor?
 - Where can you change the settings?
 - If a patient rings outside of their settings, what do you do?

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