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# Use of an Alarm Bundle to Reduce Alarm Fatigue in the ICU: A Quality Improvement Project

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**Use of an Alarm Bundle to Reduce Alarm Fatigue in the ICU:**

**A Quality Improvement Project**

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A DNP project submitted in partial fulfillment of the requirements for

the degree of Doctor of Nursing Practice

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Practice Expert: Eduard Valente, MSN, RN, CCRN.

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This is to certify that the Final DNP Project Paper by

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has been approved by the DNP Project Team on

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for the degree of Doctor of Nursing Practice

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Practice Mentor: Ashely D'Agostino- Putetti MSN, RN, WCC.

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## Abstract

***Significance and Background:*** In the critical care setting, frequent false alarms can lead to sensory overload and delayed reactions to alarms (aka, alarm fatigue). Patients are at risk because overtime staff may ignore or become desensitized to all alarm sounds, even true ones.

***Purpose:*** The purpose of this QI project is to establish alarm management protocol in a 14-bed ICU. The goals were to reduce alarm fatigue and create a safe environment for patients and clinical staff**.**

***Methods:*** The Model of Improvement (IHI, 2023) with cycles of the Plan-Do-Study-Act (PDSA) was used to implement an alarm bundle checklist that included daily skin cleansing with soap, water and change of ECG electrodes. The QI project occurred over 12 weeks. Outcome measures were to see a decrease in false alarms, track adherence to the alarm bundle checklist, and see improvement in nursing perception of alarm fatigue in the ICU.

***Outcome:*** A total 1,544 cardiac rhythms were recorded based on atrial, ventricular, and false rhythms. The occurrence of false alarms prior to the alarm bundle checklist (weeks 1-6) was 44.3% (2) with a 2.3% reduction after the implementation of the alarm bundle checklist (weeks 7-12) at 42% (1). The alarm bundle adherence showed >90% completion rate except for last week of the study, which decreased to 86%. Responses (n=24) to the 11-question nursing survey showed >10% improvement by week 12 except for the question that directly asked about the occurrence of nuisance alarms, which did not change from baseline to end of study.

***Discussion:*** There was a reduction in cardiac false alarm rhythms after using the alarm management protocol. Having more PSDA cycles may lead to larger reduction and improve sustainability of the alarm management protocol.


***Keywords:*** alarm fatigue, patient safety and ICU, alarm fatigue and ICU, false alarms, and ECG electrodes.

# Problem Identification, Development of Clinical Question, & Evidence Review

## Background and Significance of the Problem

In 2019, The Joint Commission's (TJC) Sentinel Event Alert estimated 85 to 99% of alarm signals in the critical care setting were insignificant and do not require clinical intervention. TJC with the American Association of Critical Nursing (AACN) (2018) recommend daily change of electrocardiogram (ECG) electrodes after thorough cleansing of the skin to reduce the number of false alarms (Sendelbach et al., 2016). In the critical care unit, alarms serve an important function of alerting clinical staff regarding patients' health status. However, false alarms can lead to sensory overload and delayed reaction to these alarms. Nguyen et al., (2020) report 94.8% of all false alarms are related to cardiac monitor reflecting inaccurate arrhythmias or false asystole episodes not true to patients' actual clinical status. For example, consider environments or units where clinicians are surrounded by constant beeping sounds and alarms that are false. As a result, clinicians can develop sensory overload and, eventually, become desensitization to these alarm sounds. This puts patients at risk because overtime clinical staff begin to ignore all alarm sounds, even true ones, altogether. This phenomenon is known as alarm fatigue (Bi et al., 2020).

Alarm fatigue is an ongoing issue in the intensive care unit at a community hospital (GH) in Connecticut and a practice change, supported by an evidence review, will reduce sensory overload, alarm fatigue, and increase patient and staff satisfaction. According to Lewandowski et al. (2020) alarm fatigue interferes with nurses' abilities to deliver quality care, and this can have a negative impact on patient well-being. Therefore, the goal of this quality improvement project is to establish alarm management protocol at the GH to reduce alarm fatigue and create a safe environment for the ICU patients and clinical staff.

## Description of Local Problem

The community hospital's alarm fatigue protocol fails to provide guideline for managing and preventing the adverse effects of false alarms in the ICU. In 2019, the TJC reported alarm fatigue can lead to nurse burnout and effect patient safety. This finding is supported by Graham & Cvach (2016) study which showed health care workers, especially nurses, are exposed to 150 – 400 physiologic monitors and alarms per day. These monitors and alarms created a poor work and healing environment and leads to sensory overload which ultimately impacts emotional, cognitive, and physical function of health care providers and patients (Katarzyna et al., 2020).

The alarm fatigue at the GH's ICU is overwhelming for nursing staff and compromising patient safety. Baseline data obtained from the central unit monitor at the GH indicate that more than 40% of all cardiac rhythm alarms were false and did not represent actual clinical status. Therefore, implementation of an alarm management protocol at the GH is needed.

## Organizational Priority

The development of an alarm management protocol was supported by the ICU Nurse Educator, Ashely D'Agostino-Putetti MSN, RN, WC. Ms. D'Agostino-Putetti also served as practice mentor for this QI project. Eduard Valente MSN, RN, CCRN, ICU Clinical Manager, was also included in the development of the alarm management protocol.

Permission to implement the alarm management protocol was granted by Kelly Egan MSN, RN, CCRN, the Inpatient Service Administrator. Lastly, other key stakeholders for this project were the ICU clinical staff (e.g., nurses and patient care assistants) and the Chief Nursing Officer (CNO), Kimberly Richards, MSN, NEA-BC. Without the support of the ICU clinical staff, the implementation of the alarm management protocol would not be successful.

**Focused Search questions**

To establish the best practices for reducing alarm fatigue in the ICU, an evidence search was completed by the project leader (PL), Blerina Petitti. To guide the evidence search, the PICO format was used:

In the critical care setting (P), how does daily ECG electrode change (I), compared to current practice (C), reduce false alarms (O)?

**Evidence Search**

An evidence review in the following databases: CINAHL, MEDLINE, and the Cochrane Database of Systematic Reviews was conducted. The key words searched were alarm fatigue, patient safety, ICU patients, false alarms, ECG electrodes, skincare, burnout, sensory overload, and alarm fatigue and nurses' perception. Limiters used were English language and published between 2016– 2022. Inclusion criteria for article selection were alarm fatigue and patient safety, and intervention for reducing false alarms and sensory overload. The Rapid Critical Appraisal Tools (Melnyk & Fineout-Overholt, 2019) was used to appraise each of the keeper articles. Appendix A provides a description of the evidence plan search. Seven articles met inclusion criteria (e.g., addressed the effects of alarm fatigue and interventions to reduce false alarms in the ICU) and used to establish guidelines for alarm management protocol (Please refer to Appendix D for the Evidence Review Table). The level of evidence for each is as follows: one level I (Bi et al., 2020), two level II and III (Lewis et al., 2019; Nguyen et al., 2020) one level IV (Sendelbach et al., 2016), two level V (Lewandowski et al., 2020; Graham & Cvach, 2016) and one level VI (De Vaux et al., 2017). Please refer to Appendix E for critical appraisal of all 7 articles. The appraisal includes Table E1 (Level of Evidence) and Table E2 (Outcome Synthesis).

**External Evidence**

### *Effects of Alarm Fatigue*

As mentioned previously, monitors and alarm systems in the ICU reflects patients' health status. The alarms alert ICU clinical staff of the need to respond or check on their patients. However, continuous exposure to false alarms which leads to alarm fatigue and may result in delayed or lack of response (Graham & Cvach 2016). According to Bi, J, Yin et al. (2020) alarm fatigue can have negative consequences on patient safety and the management of false are an obstacle in ICUs. A survey (n=389) by Lewandowski et al. (2020**)** provides additional evidence. Their survey found 93% of nurses ignored clinical alarms, 81% admitted it was mainly due to the high number of false alarms, and 52% do not know how to reduce alarm fatigue.

### *Interventions to Reduce False Alarms*

A study by Sendelbach and colleagues (2016) showed the total number of false alarms decreased by 17.6% with the use of an alarm bundle checklist. This bundle included 24 hours ECG electrode change, daily skincare, and dating the ECG electrodes every day for 6 weeks period. In a similar study by Lewis et al. (2019), the total number of false alarms decreased from 52% to 31% with implementation of a similar intervention. They also found nurse perception of alarm fatigue improved with the reduction in false alarms. Additionally, Lewis and colleagues' (2019) study found the use of protocols for management for alarm fatigue and staff education improved alarm response rate. In Nguyen et al. (2020) study, they found alarm response increased from 43.1% to 62.1% after adapting daily skincare with soap and water and ECG electrode change every 24-hours. Another study by De Vaux et al. (2017) found using alarm management practices (e.g., daily ECG electrode change) were directly related to a reduction of false alarms rates. In their study, the false alarms decreased from 201 to 12 in a year (March 2014 – February 2015) after implementation of these practices. Lastly, both TJC (2019) and

AACN (2018) recommend daily cleansing of the skin with soap and water and ECG electrode change every 24 hours to reduce false alarm rates and alarm fatigue in the critical care setting.

**Internal Evidence**

As mentioned previously, the GH's protocol for the management of false alarms and alarm fatigue in the ICU fails to provide specific guidelines. Currently, ECG electrode change follows nursing judgment. For example, nurses will perform skin prep and change ECG electrodes when they become soiled or as result of poor connection to the patient's skin as needed, not daily. The GH's ICU has a high rate of false alarms. Responding to these false alarms increases workload and this can lead to burnout and decrease response to alarms (e.g., alarm fatigue). This can compromise patient safety because clinical staff may ignore a true emergent alarm!

**Evidence appraisal, summary, and recommendations**

Based on the evidence review, the GH's new protocol for alarm management in the ICU will include daily skin cleansing with soap, water and change of ECG electrodes every 24-hours. This should help reduce the number of false alarms and improve nurses' perception of alarm fatigue in the ICU.

## Phase 2: Project Plan

**Project "SMART" goals**

1. Establish best practices for management of false alarms and alarm fatigue in the ICU at the GH.
    - Development and use of clinical alarm bundle checklist
2. Reduce the number of false alarms and improve nurses' perception of alarm fatigue in a 12-week period.

3. Establish and sustain use of the alarm management protocol at the GH.

**Context**

As mentioned previously, the GH has no formal protocol to manage false alarms and/or alarm fatigue in the ICU. As discussed earlier, alarm fatigue can have detrimental effect on both health care providers and patients. Therefore, it's imperative the GH establishes a protocol to combat alarm fatigue in a 14-bed ICU. Patients treated in the GH's ICU are adults 18 years of age or older undergoing medical and/or surgical procedures. The staff includes 3-intensivists, clinical manager, nurse educator, and 24-registered nurses. Staffing shortage is a major concern for this ICU pre- and post-COVID pandemic. With high-turnover rates, nurse to patient ratios have increased. Before pandemic, the nurse-patient ratios ranged from 1:1 or 1:2. Since the pandemic, the nurse-patient ratios has been 1:2 or 1:3. However, some days the ratio is as high as 1:4. When you combine the effects of a higher patient load with excessive alarms and needing to respond to them, nurses can feel overwhelmed. This ultimately leads to alarm fatigue which can jeopardize patient safety. Therefore, the short-term goal of this QI is to reduce rates of false alarms and improve nursing perception of alarm fatigue. The long-term goal is to improve patient safety.

**Project Team Members and Roles**

This QI improvement project included three phases the pre-implementation, implementation, and evaluation phase. During the pre-implementation, results of the average percentage of false alarms were reported to the Practice Mentor, Clinical Manager, and Inpatient Service Administrator. It was during this phase, awareness and support for the project was gained. Implementation phase required the support from ICU clinical staff. Their roles and how to gain buy-in is discussed in the next section. The PL, Blerina Petitti, collected and analyzed QI

study data for this project. QI project plan, implementation, and evaluation was developed with the guidance of the PL's Faculty Advisor, Rosemary Johnson DNP, APRN, ANP-BC, Practice Mentor, Clinical Manager, and Inpatient Service Administrator.

**Key stakeholders and Buy-in**

Implementation of the alarm management protocol involved a multidisciplinary team including physicians, nurse practitioners, staff nurses, nursing assistants, and medical engineers. Education was the key component for successful implementation of the new protocol. The initial phase focused on clinical staff's current knowledge of the adverse effects of alarm fatigue. The goal was to gain buy-in and highlight the importance of utilizing best practices for reducing false alarms, preventing staff burnout and alarm fatigue, and improving patient care. Lastly, staff nurses had support from the PL, education department, and clinical manager of the ICU. The PL utilized unit champions and leaders who were interested in reducing false alarm rate in the ICU. The PL already had some nurses willing to assist in the practice change and policy update for false alarm management prior.

**Framework**

This QI project followed the Institute for Healthcare Improvement's Model for Improvement (IHI, 2023). This framework was chosen to guide implementation of the QI project because this framework is effective in producing and sustaining process or behavioral changes in an organizational setting. The first part of the MFI is to identify a process change or an organizational problem that needs improvement. Three questions are addressed in this phase: (a) what the goals of the project are, (b) what assessment tools are needed to evaluate the outcomes, (c) what process changes can be made to result in the improvement and how to sustain the

change long-term. The MFI utilizes cycles of the Plan-Do-Study-Act (PDSA). These PSDA cycles allowed the project team to adapt to changes in the real work setting.

During the "Plan" phase two components took place, the problem or process change being study and the specific roles of the QI project team (creating awareness and buy-in). The "Do" phase focused on the implementation of the plan and documentation of outcomes (e.g., intervention/process change). During the "Study" phase, the actual outcomes of the project were compared with expected outcomes. Lastly, the "Act" phase focused on the evaluation of the results and decided one of the following: (a) expand the success in other areas, (b) readjust the goal(s), (c) change strategy, and (d) reevaluate the etiology of the problem (Dawson, 2019a).

## Plan phase

### *Create Awareness*

The PL met with all team members and stakeholders to create awareness and interest for the new alarm management protocol and use of the alarm bundle checklist (further details given in the Do phase). The PL sought input and support from the ICU nursing staff, nursing assistants, unit clinical manager, and nursing educator. Project goal #1 was completed during this phase. The PL shared the recommendations from TJC (2019) and AACN (2018) and the evidence review with team members and key stakeholders, as well as organizational leaders to ensure support and success of implementing the new alarm management protocol at the GH.

### *Building Knowledge, Commitment, & Buy-in*

The next step of the plan phase was to build knowledge, commitment, and buy-in (Cullen et al., 2018). To achieve this, the PL held educational sessions during each shift/staff meeting with ICU clinical staff. During the initial educational session, the PL selected "change" champions or leaders. The "change" champions helped ensure commitment to adhering to alarm

management protocol and use of the alarm bundle checklist. According to De Vaux et al. (2017) effective translation of evidence into practice requires educating staff effectively. Other educational strategies included handing out flyers and pamphlets regarding the new protocol and the alarm bundle checklist to staff not able to attend the in-person meetings. Kumah et al. (2019) outlined that clinical staff are more likely to change behaviors and willing to accept new practices through multiple forms of educational strategies and initiatives.

Once the “change” champions were selected, they were trained on the alarm bundle checklist. The goal was to have at least one champion per shift. The champion would be responsible to educate, train and remind clinical staff on the completion of alarm bundle checklist daily. According to Cullen et al. (2018), having “change” champions or leaders are essential for any policy or practice change initiative. The ICU clinical manager and nurse educator would also act as “change” champions as they met weekly with all ICU staff and the PL. They were responsible to address questions or concerns ICU staff may have and bring to the attention of the PL. The PL met weekly with all “change" champions to discuss the project goals, implementation process, and share insights on the effect of the new alarm management protocol and alarm bundle. Lastly, the PL sent weekly email reminders to encourage staff to fill out anonymous suggestion envelops around the education board. The PL reviewed these weekly as well.

## Do Phase

### *Intervention/Process Change: Alarm Bundle Checklist*

This QI project will take place in a 14-bed ICU at the GH over 12 weeks. Project goals number #1 & 2 will be completed in this phase. The nurses’ perception towards false alarms will be evaluated using a questionnaire (see Appendix F for details). This is a 11-question survey that

focuses on two main areas: their knowledge of physiologic alarm management and the effects of alarm fatigue. Nurses will be given the questionnaire at baseline, week 6, and week 12 (end of QI study period).

The alarm bundle checklist includes daily removal of ECG electrodes, washing skin (chest) with soap and water, drying with washcloth, placement of new ECG electrodes, and dating the electrodes, regardless of whether electrodes look soiled or still adhering to skin. The nurses would complete electrode management care form (see Appendix G for copy of the form) to show daily skincare and change of electrodes are completed. This form was included with the 24-hour ICU flow sheet. Once completed, the nurse would return each form to boxes designated at the nurse's station before the end of the shift. PL collected all forms from designated boxes weekly.

The alarm bundle checklist was included in the patient's daily hygiene care. It took place between 4 and 6 am and performed by the night shift nursing staff. To ensure implementation of this new protocol, 4 nurse champs (2 on the day shift and 2 on the night shift) were selected. Once they completed the training process, they served as "change" champions for staff nurses.

The alarm rates were recorded and evaluated from the central unit monitor. Data was collected during a 6-week period prior the implementation of the alarm bundle checklist and 6 weeks after. Each week, the project leader obtained the alarm rates from the central unit monitor and recorded alarms are based on whether they are atrial, ventricular, or false.

As mentioned previously, nursing survey given at baseline, week 6, and week 12. Surveys were given to nurses at the start of each shift, during the appropriate measurement period. Nurses were allowed to anonymously complete survey and put survey in a designated box at the nurse's station.

**Study Phase**

The actual outcomes are compared to the project goals and outcomes of this QI project. The goals of this QI project were to: (a) reduce the total number of false alarms in a 24-hour period measured by alarm rates pre -and post- alarm bundle checklist use and (b) obtain nursing satisfaction/perception of false alarms in the ICU via survey. The following SMART goals were used to determine effectiveness of the alarm bundle checklist:

- Reduction in false alarms rates by 5-10% 6 weeks after implementation
- Improved clinical staff perception of alarm fatigue by 5-10% over the 12-week study period.
- Track adherence to the false alarm checklist bundle with at least 90% completion of electrode management care form 6 weeks after implementation

**Act Phase**

Project goal #3 was addressed during this phase. The project leader determined whether alarm management protocol and/or alarm bundle needed revision based on the first PDSA cycle of the QI project.

**Possible Barriers to Implementation**

The alarm bundle checklist would be completed during the night shift and included in the patient's daily hygiene. Normally, changing ECG electrodes occurred on any shift and at any time. However, the night shift nurses could feel the alarm bundle checklist adds additional work for them (e.g., in the form of having to perform daily skincare, ECG lead changes, and documentation of the electrode management care form). This was a potential barrier the PL needed to overcome.

**Sustainment**

To overcome possible barriers and improve sustainment, regular meetings took place on the ICU. At these meetings, celebration of and acknowledge of staff who completed the alarm bundle checklist were given in the form of award certificates. Food and snack were shared with all ICU nurses who contributed to the completion of this QI project.

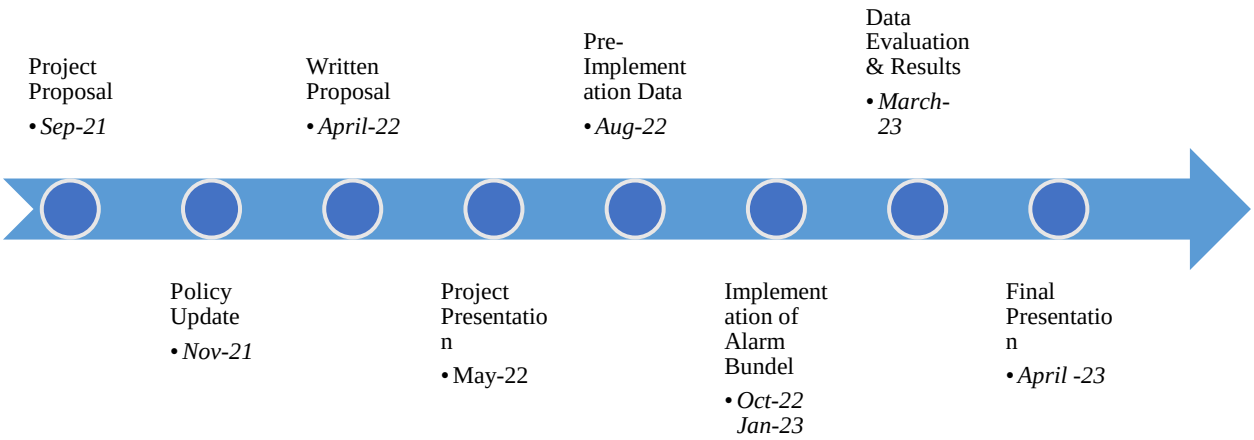
**Dissemination**

The dissemination plan includes informal presentation of QI results to staff nurses, nursing educators, clinical manager, medical, and administrative staff. The presentation will take place at the end of the data collection period in unit conference room.

External stakeholders such as patient and the surrounding community members who utilize the CH for care will receive notification of this QI project via the hospital's website and newspaper. Lastly, a formal PowerPoint presentation will be given to the site mentor, nurse manager, and at the CH's EBP workshop scheduled in May 2023. Hopefully, the latter will provide the project leader the opportunity for future collaboration on other QI/EBP projects.

**Estimated Timeline**

**Figure 1.** *Project timeline*



**Resources**

The cost analysis for this QI project included the time to collect and analyze pre- and post-implementation data, education services for nursing staff, and evaluation of the electrode management care forms. All these steps are planned to take place during work hours and will not require overtime work from ICU nurses or the PL. Additional cost not included in this report would be the cost of the ECG electrodes used pre and post implementation alarm bundle checklist. Table 1 depicts the project anticipated cost. The Project leader's time was calculated by multiplying the anticipated hours spent on the project (approximately 80 hours) multiplied by the hourly rate of $42.68 for an ICU, RN's annual salary of $88, 782. Additional cost included were celebrations and paper for the nursing survey and EMC form. The final project cost is provided in Appendix I, Table I1.

**Table 1:** *Anticipated Project Costs for Implementation and Evaluation*

| | **Estimated Project Cost** |
|---|---|
| **Project Leader Time**<br>3.8% of average ICU RN annual salary $ 88,782. | $3414.40 |
| Nursing Education Presentation<br>Coffee & Breakfast | $48.00 |
| Nursing Education<br>Presentation<br>Afternoon Snacks | $35.00 |
| Nursing Education Presentation<br>Unit Celebration & Acknowledgments | $75.00 |

| | |
|---|---|
| Custom Pocket Guides (alarm bundle checklist) x 20 colored; paper to print nursing survey & EMC forms | $60.00 |
| **Total Cost** | $3632.40 |

## Ethical Consideration

This is a QI project and an IRB wan not required by the community hospital. This project did involve human subject but did not involve any experimentation or access to identifiable personal information. Refer to Appendix B, Table B1, for detailed information identifying why this DNP project qualified as QI. The project proposal was submitted to Sacred Heart University's IRB and received exempt status on June 23rd, 2022 (please see Appendix C for details).

## Phase 3: Project Implementation & Barriers Encountered

### Project Implementation

The implementation phase took place from October 30th, 2022, till January 21st, 2023. Pre-implementation data was collected for six weeks between October 30th – December 10th, 2022. Followed by implementation period between December 11th, 2022 – January 21st, 2023. The educational strategies detailed above were implemented. The QI project was initially introduced during the change of shift meeting/huddle a week before the study (week 0 of the study) followed by an email one week later (week 1 of the study).

One educational seminar (total of 5 hours) was given to both day and night ICU shift during the first week on the study. Emails were sent every week to ICU staff thereafter reminding staff to complete the alarm bundle checklist. Posters and flyers were also placed on

the unit communications board to serve as additional reminders. Lastly, reminders to complete the alarm bundle checklist was also part of the change of shift huddles. The educational strategies detailed earlier were used to promote sustainability, address possible barriers, and get ICU staff feedback on the successful use of alarm bundle checklist.

The false alarms rates were collected as planned manually from the central unit monitors and recorded and analyzed using Excel spreadsheet. For each patient on the ICU, there is a 24-hour reading of alarms broken down into atrial, ventricular, and false. The PL collected all patient data on weekly bases.

The PL collected alarm rates 6 weeks prior to the use of the alarm bundle checklist and 6 weeks after. By the end of the 12-week study period, a total of 136-patients was admitted to the GH's ICU. The administration and completion of the nursing survey took placed as planned, at the start of the project (baseline) followed by repeat survey at week 6 and week 12. Lastly, the completion of the electrode management and care forms was collected weekly, from designated boxes, for 6 weeks by the PL and all data was recorded and analyzed using Excel spread sheet.

Even though the project was successfully started and ended at the time that was planned, there were a few challenges that affected adaption of the project from the beginning. These barriers were addressed during the Act phase of PDSA cycle. The major barrier encountered was lack of adherence or completion of the alarm bundle checklist, staff turnover, and lack of priority for the nursing staff. Surprisingly, there was no issues with completion and return of the nursing survey. All 24 nurses working on the ICU completed and return surveys for each survey period (e.g., baseline, week 6 and 12).

## Barriers to Implementation

### *Lack of Time to Complete the Electrode Management and Care (EMC) Form*

ICU settings are unpredictable and change in the patient's health status takes priority (AACN, 2018). At times, nurses found it difficult to take care of the ICU patients and complete all required documentation by the end of their shifts. Therefore, most would stay after their shift to complete the "required" documentation. However, with the addition of the EMC form for completion, which was not in the EMR, added to nursing workload and was easily missed. In some cases, the nurses did complete most steps of the alarm bundle checklist (e.g., the daily skin cleansing and change of ECG electrodes) but failed to fill out the EMC form. Even though there were frequent reminders during change of shift huddles and weekly meetings, there were instances where the EMC form was missed (see Appendix G, Table G1, for further details).

### *Staff Turnover*

Another challenging factor that was brought to the PL, by nurse champions, was the staff turnover. Nursing shortage and increased patient demand required staffing from the float pool, travel nurses, and per diem staff. It made education and informing these nurses about the alarm management protocol and alarm bundle checklist difficult and time consuming. With the assistance of the nurse champions, additional educational sessions were put in place to address knowledge gap of nonregular ICU nurses. It was found that the "nonregular" ICU nurses were the ones that failed to complete the alarm bundle checklist. During data analysis process, the lack of daily hygiene care, daily ECG electrodes change and dating, and completion of the EMC form was mostly in this group of nurses.

### *Priority of the QI Project*

The ICU is an environment that is high paced and constantly changing. The COVID-19 pandemic called for rapid changes in protocol to ensure high level of care in extremely challenging conditions. For instance, national and state level guidelines were followed on

specific areas including organization visitation policy, safety equipment application (e.g., dawning masks and gowns), and immunization status (visitors and hospital staff) to assist and improve the care of ICU patients (AHA, 2020). These continuous updates were a burden not only for nursing staff, but for the entire interdisciplinary team at the GH. For most of the GH's staff, it was difficult to keep up with all these changes and follow the specific national, state, and/or organizational policies. Furthermore, these challenges increased overall pandemic fatigue ─ a concept where the pandemic-related stressors reduced the likelihood to follow appropriate guidelines for protective behavior (AHA, 2020). Some viewed completing the alarm bundle checklist as an increase in workload and found it difficult to adapt project steps right away.

## Phase 4: Evaluation (Process & Outcome Measures & Return of Investment)

### Process Measures

The data collection period occurred over 12 weeks. Inclusion criteria was adult patients > 18 years of age in the ICU at the GH. Patients who did not require ICU level of care (e.g., telemetry or general medicine holds were not included in this study. A total of 136 patients' cardiac rhythms was collected and recorded based on atrial, ventricular, and false rhythms. PL recorded a total of 1,544 rhythms and reported findings in frequencies (e.g., actual number of atrial [$f^1$], ventricular [$f^2$], and false [$f^3$] alarms). To calculate the percentage (%) of false alarms (reported by week), the formula of total number false alarms divided by the total number of alarms (sum of all 3 alarms) x 100 was calculated. All findings are reported in Appendix G, Table G1, in the appendices.

As mentioned previously, all registered nurses who participated (n=24) in the implementation of the alarm bundle checklist and completed the nursing survey at baseline, week 6 and 12. The results of nursing survey are represented in frequency (***f)*** and percentage (**%**) of

each answer responses (e.g., agree, neutral, and disagree) for each of the 11 questions. All findings are reported in Table F2 located in Appendix F.

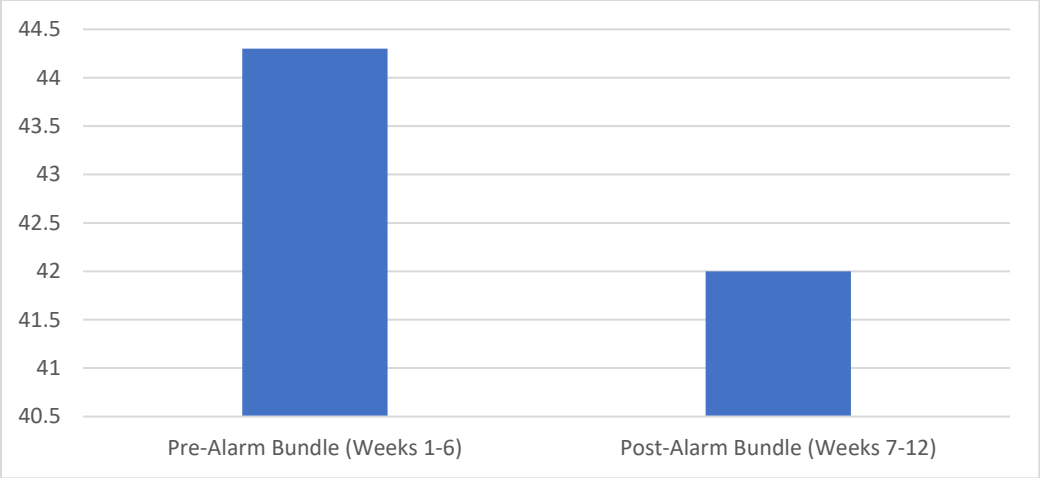
The EMC forms were collected from weeks 7 to 12 of the study period. The results of adherence or completion of the EMC forms were recorded in frequency (***f***) and percentage (%) of forms completed by week. All findings are reported in Table GI in Appendix G.

**Outcome Measurements**

The first SMART goal of project was to see a 5-10% reduction in false alarms 6 weeks after alarm bundle implementation. During the pre-alarm bundle weeks of 1 thru 6 there was a total of 807 alarms, 358 of were false alarms. During the post-alarm bundle weeks of 7 thru 12, there was a total of 737 alarms, 310 were false alarms. The figure below represents the average percentage of false alarms pre-alarm bundle and post-alarm bundle. While the project goal of a 5-10% reduction in false alarm was not achieved, there was a 2.3 % reduction in false alarms after implementation of the alarm bundle. Reason for not achieving project goal could be related missteps in the of the alarm bundle checklist. For instance, there were times where the documentation of EMC form was not completed and/or missed or the nurses or patient care assistants did not complete all steps of the intervention (e.g., daily skin care and ECG lead change) this could have affected the results.

**Figure 2**

*Average Percentage (%) of False Alarms*[**]




*Standard Deviation.

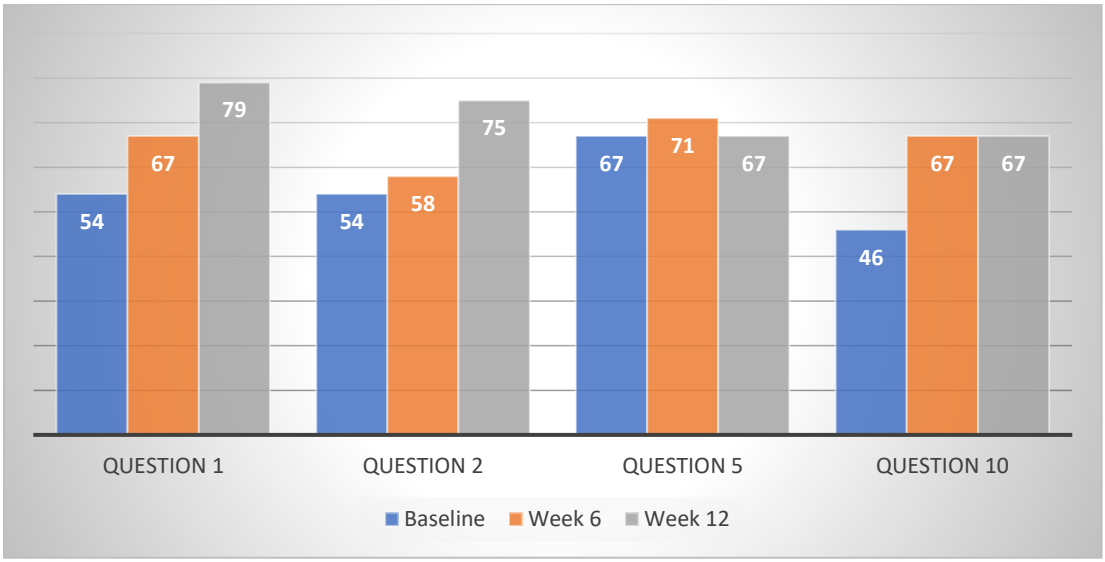
**Note: % of false alarms was calculated by the sum of the weekly false alarms divided by sum of all (e.g., atrial, ventricular, and false) weekly alarms x 100. Average false alarm rate pre-alarm bundle was 44.3% (SD*= 2). Average false alarm rate post-alarm bundle was 42% (SD= 1).

The second SMART project goal was to improve nursing perception of alarm fatigue by 5-10% over the 12-week period. Responses to questions 1, 2, 5, and 10 were used to illustrate improvement in nursing perception of alarms in the ICU. For example, question #1 asked whether the purpose of clinical alarms is to alert staff of hazardous patient conditions. At baseline 54% agreed, 67% agreed at week 6, and by week 12, almost 79% of nurses agreed. Question #2 asked whether alarms sounds and/or visual displays should differentiate different alarm priority. At baseline, 54% agreed, 58% agreed at week 6, and by week 12, 75% of nurses agreed. Question #5 asked whether nuisance alarms occur frequently. At baseline 67% agreed, 71% agreed at week 6, and 67% of nurses agreed at 12 weeks. Lastly, question #10 asked whether the staff is sensitive to alarms and responds quickly. At baseline only 46% agreed. However, by weeks 6 and 12, 67% of nurses agreed. Overall, responses to the 4 primary

questions showed > 10% improvement by 12 weeks except for question 5 that directly asked about the occurrence of nuisance alarms. Possible reason for not achieving an improvement in nurses' perception of nuisance alarms could be the frequency of false alarms from other monitors (e.g., ventilator, pulse oxygen, and intravenous). The level of frequencies from these false alarms may have affected their responses. For visual depiction of these finding, refer to Figure 3 below.

**Figure 3**

*Nursing Perception of Alarms in the ICU at GH*




The third SMART goal of this project was to achieve 90% completion of the alarm bundle checklist. This bundle checklist included completion of the daily skincare and ECG electrode lead change and completion of the EMC forms for every ICU patient in 24 hours. During the 6 weeks post-alarm bundle use, a 90% or more completion rate was achieved during weeks 7 thru 11. Week 12 of the study showed a decrease in EMC form documentation. The slight drop in documentation in the final weeks was probably due to the staff shortage and inclusion of the travel and/or float staff in the QI project. Unfortunately, the COVID-19 pandemic exacerbated existing nursing shortage and quality improvement efforts were not the

priority during the pandemic (Terwilliger et la., 2022). As a result, sustainability with the alarm management protocol was challenging and required utilization of second PDSA cycle in week 9 to adapt change in real time. Refer to Figure 4 below for the flow chart of the weekly percentage of EMC form documentation.

**Figure 4**

*Percentage (%) of Weekly Documentation of EMC Forms*


*Note:* % calculated by number patients on unit divided by completion of EMC forms x 100.

**Return On Investment**

ROI can be viewed from the benefits of reducing alarm fatigue in the ICU setting. As mentioned previously, alarm fatigue can negatively affect clinical staff and patients. Alarm fatigue can result in nurses feeling burned out, overwhelmed, and overworked from responding to numerous false alarms and the sensory overload. Overtime, patient care suffers as result of desensitization to the sounds and lack of response to true emergent alarms. Based on the nursing survey, perception of sensitivity to alarms and response rate improved after the alarm bundle

implementation. Therefore, any intervention that strives to improve patient care and work environment for clinical staff will yield positive returns for the GH.

Lastly, the total dollar amount spent on this project is based on initial cost analysis comparison to final total cost (refer to Appendix I for final cost table). Unfortunately, cost of electrode leads pre and post alarm bundle use was not calculated for this QI project. When the PL was trying to gain this data early in the planning process, the ability to access this information required going outside of the ICU department. Therefore, the true cost of daily electrode lead change compared to standard practice (change as needed) cannot be ascertain. Also, the PL initially anticipated personal hours spent on this project to be approximately 80 hours. However, an additional 5 to 8 hours was added for total of 88 hours of time spent. An additional 10-15 minutes of nursing time per patient was also added for completion of the alarm bundle checklist to the final cost analysis. This information came directly from nursing staff input during the 2nd PDSA cycle. For further details of time spent on implementing alarm bundle checklist refer to Table H1 located in Appendix H.

## Phase 5: Dissemination

### Implications of Project Results to Organization and Practice

This QI project was instrumental in establishing an effective protocol in managing cardiac false alarms in an ICU. Implementing the use of an alarm bundle checklist resulted in a reduction of number of false alarms and improvement in nurses' perception of clinical alarms. These results are consistent with other quality improvement projects that sought to reduce alarm fatigue in the ICU setting. (AACN, 2018; Bi et al., 2020; Sendelbach et al., 2016). As a result, the findings from this QI project will add to the body of evidence on how to effectively reduce alarm fatigue.

In summary, the goal of this project was to create a safe environment for the ICU staff and patients. The findings show that nurse's perception towards clinical alarms did improve with continuing education on alarm fatigue management. This QI project highlights the role of evidence-based practice and the importance of having support from within an organization (e.g., educational department, clinical leadership, and management) to be successful in improving the quality of patient care (Lee et al., 2021)

**Sharing Project Results Locally and Regionally**

An executive summary will be presented to all members of educational department at the community hospital, the ICU Clinical Manager, and the Inpatient Administrator. The final written DNP project paper will be upload to Sacred Heart University's Repository; this will allow dissemination of findings to students and professional colleagues to use as supporting evidence in future QI projects. A poster presentation of the study and findings will be present at the at the College of Nursing on April 21st, 2023. Attendees of the poster presentation will include SHU's Nursing faculty, peers, family, and friends. Lastly, the project will be published in the organization newspaper by June 2023 to share the results with colleagues and the surrounding community that utilizes the hospital for service.

**Key Lessons Learned**

First key lesson learned was the importance of team support, collaboration, and open communication were fundamental for project success. This was evident by the >90% completion of the EMC form during weeks 7 thru 11. However, there was a drop noted in week 12 resulting in 84.6% completion. As mentioned previously, the decrease was most likely due to staff shortage and having nonregular ICU nurses from the float pool and/or travel agency covering.

Even though the nonregular nurses were educated on alarm bundle, the inconsistency in coverage lead to disruption in the alarm management protocol.

Second lessoned learned would be to improve the nursing survey. While 3 of the 4 main questions that illicit nurses' perception of alarms in the ICU were positive, the PL realized one of the questions could have been misinterpreted. For example, the question on the level of nuisance alarms on the unit should have focused on the cardiac monitor alarms. Nurses may have answered the question based on all of the other alarms (e.g., ventilators) in the unit. Therefore, the nurse perception survey will need to be revised for future uses. Another option could be providing brief educational session before each survey to better explain the questions to participants.

Third lesson learned was that 6 weeks for implementation of the alarm bundle might not have been sufficient time to achieve the desired results. Given the results achieved in this QI project, a statement could be made that data collection longer than 6 weeks will lead to better results. Similar QI projects showed a larger decrease in alarm false rates with longer study period of 12 months (De Vaux et al. 2017). Even though establishing an alarm management protocol was an organizational priority, other priorities took precedence. As discussed earlier, nursing shortage and increased hospitalization for COVID effected the implementation and outcomes of this QI project. Running more PDSA cycles may positively affect the implementation and sustainability of the alarm management protocol.

Lastly, the culture of change requires collaboration of the entire interdisciplinary team. Future projects could benefit from creating a EBP change team that will help future projects and support members at different stages of implementation.

**Sustainability Plan**

One way to ensure sustainability of the alarm management protocol is to move the documentation of the EMC form into electronic medical records (EMR). Nurses on the ICU expressed concerns about having to document the EMC form outside of EMR. The PL had to add an additional 10-15 minutes of nursing time to allow for this. Another way to ensure sustainability and reduce false alarms is having a patient care assistant (PCT) on each shift assigned to check whether the ECG electrode leads were changed in a 24-hour period. Sometimes the daily skincare and ECG electrode lead change occurred on one shift while documentation of completion occurred on the next. The PL cannot be entirely sure if the daily skincare and lead change was performed during these occurrences. Per the protocol, once the leads are changed, the date and time should be recorded. If not done, the designated PCT responsible for checking will complete the skincare, change ECG electrode leads, and place date/time on the leads. Lastly, this PL believes extending the data collection period for another 6-12 weeks with the changes above will most likely produce a greater reduction in cardiac false alarms.

**Summary**

This QI project set out to establish an effective cardiac alarm management protocol at the GH's ICU. The results show the use of an alarm bundle checklist was effective in reducing cardiac false alarms modestly. In the future, other QI studies can focus on managing alarms from mechanical ventilator, O2 monitor saturation, and intravenous pumps. All these medical devices can produce false alarms and contribute to a clinical environment surrounded by excessive noise. Other outcome indicators can measure patient perception of alarms in the ICU and see if reducing false alarms has an impact on anxiety.

Future interventions can also focus on modifiable variables such as nursing staff workload, the work environment, hours of work, and situational factors such as interruptions and other causes of increase noise levels. All these variables can produce stress and affect cognitive function and lead to mental fatigue (Bi et al., 2020). For these interventions to be successful, the organization requires a culture change in the acute and critical care settings. Support must come from the both the administrative and clinical levels. The success of implementing evidence-based or QI project should be shared across the healthcare organization.

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# Appendix A

Description of Evidence Search Plan

A comprehensive review using the following databases was conducted; CINAHL, MEDLINE, and the Cochrane Database of Systematic Reviews. The key words searched were alarm fatigue, alarm fatigue use of EBP management strategies, alarm fatigue and patient safety, alarm fatigue in ICU patients, false alarms and ECG sensors, false alarms and daily ECG change, implementation for reducing false alarms, bundle care for reducing false alarms in the ICU, ECG sensors and alarm fatigue reduction, and alarm fatigue and nurses' perception. Keywords "false alarms" and "patient safety" narrowed the initial search. Limits/filters for alarm fatigue include English language, published between 2016 – 2021. Limits/filters for all searches pertaining safety concern included patient safety, English language and published between 2016-2021. Inclusion criteria for article selection were alarm fatigue and patient safety, intervention for reducing alarm fatigue, and implementation of EBP guidelines for reducing alarm fatigue. The database, search terms, and results are presented on Table A1, A2, and A3.

**Table A1**

*CINAHL Complete Search Terms and Search Results*

| Search Terms | Number of hits | Number of title & abstract reviewed | Number of full-text articles reviewed | Number of articles selected for this review without duplicates |
|---|---|---|---|---|
| *Alarm fatigue use of EBP management strategies* | *1203* | *65* | *30* | *2* |
| *Alarm Fatigue* | *315* | *43* | *5* | *2* |
| *Alarm fatigue and patient safety* | *116* | *30* | *3* | *1* |
| *Alarm fatigue in ICU patients* | *2* | *1* | *1* | *1* |

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|---|---|---|---|---|
| *False alarms and ECG sensors* | *269* | *36* | *4* | *1* |
| *False alarms and daily ECG change* | *375* | *32* | *3* | *1* |
| *Implementation for reducing false alarms* | *350* | *45* | *3* | *1* |
| *Bundle care for reducing false alarms in ICU* | *578* | *40* | *3* | *1* |
| *ECG sensors and alarm fatigue reduction* | *287* | *28* | *3* | *1* |
| *Alarm fatigue and nurses' perception* | *7* | *3* | *3* | *1* |

**Table A2**

*Medline Search Terms and Search Results*

| **Search Terms** | **Number of hits** | **Number of title & abstract reviewed** | **Number of full-text articles reviewed** | **Number of articles selected for this review without duplicates** |
|---|---|---|---|---|
| *Alarm fatigue* | *224* | *20* | *2* | *1* |
| *Alarm fatigue use of EBP management strategies* | *910* | *35* | *3* | *1* |
| *Alarm fatigue and patient safety* | *74* | *18* | *2* | *1* |
| *Alarm fatigue in ICU patients* | *1* | *1* | | |
| *False alarms and daily ECG change* | *948* | *46* | *3* | |

| | | | | |
|---|---|---|---|---|
| *Implementation for reducing false alarms* | *918* | *56* | *2* | |
| *Bundle care for reducing false alarms in ICU* | *1266* | *6* | | |
| *ECG sensors and alarm fatigue reduction* | *624* | *17* | *3* | |
| *Alarm fatigue and nurses' perception* | *6* | *3* | *1* | *1* |

**Table A3**

*Cochrane Database of Systematic Reviews Search Terms and Search Results*

| **Search Terms** | **Number of hits** | **Number of title & abstract reviewed** | **Number of full-text articles reviewed** | **Number of articles selected for this review without duplicates** |
|---|---|---|---|---|
| *Alarm fatigue* | *1* | *1* | *1* | *1* |
| *Alarm fatigue use of EBP management strategies* | *1* | | | |
| *Alarm fatigue and patient safety* | *1* | *1* | *1* | *1* |
| *Alarm fatigue in ICU patients* | *2* | | | |
| *False alarms and daily ECG change* | *3* | | | |
| *Implementation for reducing false alarms* | *7* | *1* | *1* | *1* |
| *Bundle care for reducing false alarms in ICU* | *10* | *1* | | |

| | | |
|---|---|---|
| *ECG sensors and alarm fatigue reduction* | *1* | |
| *Alarm fatigue and nurses' perception* | *1* | *1* |

# Appendix B

Ethical Review

## Table B1

*Differentiating Quality Improvement and Research Activities Tool*

| Project Description | Yes | No |
|---|---|---|
| **Purpose:**<br>**Is the activity intended to improve the process/delivery of care while decreasing inefficiencies within a specific health care setting?** | X | |
| **Scope:**<br>**Is the activity intended to evaluate current practice and/or attempt to improve it based upon existing knowledge?** | X | |
| **Evidence:**<br>**Is there sufficient existing evidence to support implementing this activity to create practice change?** | X | |
| **Clinicians/Staff**<br>**Is the activity conducted by clinicians and staff who provide care or are responsible for the practice change in the institutions where the activity will take place?** | X | |
| **Methods**<br>**Are the methods for the activity flexible and include approaches to evaluate rapid and incremental changes?** | X | |
| **Sample/Population**<br>**Will the activity involve a sample of the population (patients/participants) ordinarily seen in the institution where the activity will take place?** | X | |
| **Consent**<br>**Will the planned activity only require consent that is already obtained in clinical practice, and could the activity be considered part of the usual care?** | | X |
| **Benefits**<br>**Will future patients/participants at the institution where the planned activity will be implemented potentially benefit from the project?** | X | |
| **Risk**<br>**Is the risk to patients/participants no greater than what is involved in the care they are already receiving OR can participating in the activity be considered acceptable or ordinarily expected when practice changes are implemented within a health care environment?** | X | |

**This QI Summary Template was inquired from Duke University https://irb.duhs.duke.edu/. and was adapted from the Yale University IRB.*

## Appendix C

Sacred Heart University

Institutional Review Board: Exemption Form

Submit (by mail) completed form to:
Funda Alp, Executive Director
Office of Sponsored Programs
Sacred Heart University
Alpf1@sacredheart.edu
Tel: 203-396-8241

Proposal Title: Use of an Alarm Bundle to Reduce Alarm Fatigue in the ICU:

A Quality Improvement Project.

Investigators: Blerina Petitti BSN, RN.

Department: DNP-FNP program

Student __X__ Faculty____

Address: 105 Quaker Farms, Rd, Southbury, CT. 06488.

Email Address: petittib@mail.sacredheart.edu

Telephone Number: 203-751-2134

Faculty advisor (if student): Rosemary Johnson DNP, APRN, ANP-BC.

Advisor/chair approval: Yes _X__ No____

June 23, 2022.

Dear Applicant,

Thank you for your submission to the IRB requesting exempt review. Based on the application submitted, the IRB is pleased to approve your submission and we wish you great success in your research.

Sincerely,
Christopher Taber
Chair, IRB

# Appendix D

## Critical Appraisal

Search Question PICO Format: In the critical care setting (P), how does daily ECG electrode change (I), compared to current practice (C), reduce false alarms (O)?

### Table D

*Evidence Summary Table*

| Citation | Conceptual Framework | Design/ Method | Sample/Setting | Major Variables Studied and Their Definitions | Outcome Measurement | Data Analysis | Findings | Level of Evidence/ Quality | Quality of Evidence: Critical Worth to Practice |
|---|---|---|---|---|---|---|---|---|---|
| **Author Year Title County Funding** | **Theoretical basis for study** | | **Number Characteristics Exclusion criteria Attrition** | **Independent variables IV1 = IV2 = Dependent variables** | **What scales used - reliability info (alphas)** | **What stats used** | **Statistical findings or qualitative findings** | **Level** | **Strengths Limitations Risk or harm if implemented Feasibility of use in your practice** |
| **Article 1** | | | | | | | | | |
| Bi, Jiasi, et al. "Effects of Monitor Alarm Management Training on Nurses' Alarm Fatigue: A Randomized Controlled Trial." | Theory of planned behavior | This study was a single-blind, randomized controlled trial with two parallel groups. | The First Bethune Hospital of Jilin University, Changchun City, Jilin Province, China<br><br>RNs engaged in critical care n=68 (34 experimental & 34 control). | Independent variable- nurses behavior<br><br>Dependent Variable-Alarm fatigue for intensive care nurses.<br><br>Secondary dependent variables, the number of total alarms, non-actionable alarms, and true | Independent samples one-way ANCOVAs were used to detect differences between the two groups after the study | Wilk tests were performed on the post-tests of the numbers of total alarms, the number of nonactionable alarms and the number of true crisis alarms both in the groups. The results showed that | Reliability of likert scale used using Cronbach's α coefficient The normality of data was also tested using the Shapiro–Wilk test, and the mean (standard deviation) was used for statistical descriptions of the interval data with a normal distribution; median (interquartile range) was used for statistical descriptions of the interval data with a skewed distribution ECG arrhythmia alarms. | Level I | Strengths- using the theory of planned behavior to help decrease alarm fatigue and lowering the number of alarms. Limitations include generalizability as this was only conducted in the ICU. Inability to blind the control group due to practical reasons is a limitation due to possible contamination of control group. Total alarms was recorded but non actionable/crisis alarms were judged by experts and are subject to human error and omissions. Time- this was a short study with no longer term follow-up. |

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| | | | | crisis alarms. Clinical alarms questionnaire, which was compiled by the Japanese Occupational Health Federation, uses a likert scale. This was given to participants at at baseline and 12 weeks post intervention. On the basis of Cvach's survey of alarm numbers, the basis of Cvach's survey of alarm numbers, the "ICU Monitor Alarm Quantity Questionnaire" was prepared after onsite interviews with ICU nurses and discussion with the research team members. Expert opinion provided for any uncertainty of alarm classification. Nurses supervised the alarm recording within their work time, according to the alarm record of the monitor and the actual situation. | | all p values were higher than .05, which were in line with the normal distribution, which meant the assumptions of independent samples one-way ANCOVAs were met. | | | |

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|---|---|---|---|---|---|---|---|---|---|
| | | | | The leader of working group supervised the nurses when filling in the questionnaire and recording the alarms within 24 h daily from 7:00 a.m.–7:00 a.m. of the next day, according to the alarm record of the monitor and the actual situation. | | | | | |
| **Article 2** | | | | | | | | | |
| Lewis, Carmencita Lorenzo, and Cynthia A. Oster. "Research Outcomes of Implementing CEASE" | NA | Nonrandomized control trial quasi-experimental without comparators design | 36-bed ICU/SDU unit. The hospital is a 368-bed, not-for-profit, Magnet designated acute care facility located in an urban area in the western region of the United States<br><br>N =74 ICU/SDU registered nurses. | Independent Variable: CEASE bundle<br><br>Dependent Variable: Alarm fatigue, Number of alarms– number of auditory monitoring alarms, duration of auditory monitoring alarms> Measurement: Likert Scale- for perception of alarm fatigue with pre and posttest. | $\chi^2$ and *t*-tests determined statistical significance. | Statistical analysis was performed using SAS version 4.0 (SAS Institute, Cary, North Carolina) software. Frequency distributions and descriptive statistics describe the data. Comparisons before and after intervention were made using $\chi 2$ and independent group Student's t-test, with P < | CEASE is helpful to decrease alarm fatigue. Level 1 and 3 statistically significant. Level 2 was not.<br>Level 1, low-priority events such as low battery alerts and artifact; Level 2, moderate-priority events such as high/low blood pressure, irregular heartbeat, paired beats and high/ low SpO2; and Level 3, high-priority or life-threatening events such as apnea, asystole, ventricular tachycardia or fibrillation, and rapid oxygen desaturation. | Level III | Good study. Needs to consider further variables of noise. Not generalizable due to convenience sample. Poor posttest compliance of nurses. No Confidence Interval- limits generalizability |

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| | | | | | | .05 considered statistically significant. A power analysis was not conducted as there was no control group. | | | |
| **Article 3** | | | | | | | | | |
| Nguyen et al., (2020). Double Trouble: Patients with Both True and False Arrhythmia Alarms. | N/A. | A secondary analysis using data from an alarm study conducted at a tertiary academic medical center. | Specifically, we sought to determine (1) the frequency of patients with true and false arrhythmia alarms in a sample of 461 ICU patients; (2) patient, clinical, and ECG characteristics associated with the presence of both true and false alarms; and (3) the number and type of true and false arrhythmia alarms | Independent variables: noise alarm, noise level on unit, telemetry alarms, other equipment alarms, false alarms, alarm reason, serious changes in patients, monitoring length, replacing electrode interval, replacing battery interval, primary role, patient problems and years of experience.<br><br>Dependent variable: Predictors: Patient Problems, Serious Changes in Patients, Noise Alarm, Noise Level on Unit Alarm Reason, | A multilevel Poisson regression model was used with the unique patient variable aa a random intercept, and the coefficient for the profile status was estimated | Analyzed the data with statistics software (SPSS 25.0, IBM) All physiological waveforms (ECG), numeric vital sign measurements, alarm parameter settings, and alarms both audible and inaudible were collected from each of the 77 bedside monitors with sophisticated research infrastructure. | Of 461 intensive care unit patients, 211 (46%) had no arrhythmia alarms, 12 (3%) had only true alarms, 167 (36%) had only false alarms, and 71 (15%) had both true and false alarms. Ventricular pacemaker altered mental status, mechanical ventilation, and cardiac intensive care unit admission were present more often in patients with both true and false alarms than among other patients ($P < .001$). Intensive care unit stays were longer in patients with only false alarms (mean [SD], 106 [162] hours) and those with both true and false alarms (mean [SD], 208 [333] hours) than in other patients. Accelerated ventricular rhythm was the most common alarm type (37%). | Level III | Limitations:<br>sample size was too small to draw conclusions about efficacy. This was not the intent of this study. Second, nurses were allowed to individualize alarms; therefore, deviation from study alarm parameters was possible.<br>The study was performed on a single manufacturer's monitoring equipment.<br><br>Strengths<br>This study demonstrates a methodology for conducting a randomized controlled study design to obtain outcome data related to altering patient monitor alarm settings |

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|---|---|---|---|---|---|---|---|---|---|
| | | | | Other Equipment Alarms, False Alarms, Telemetry Alarms. | | | | | |
| **Article 4** | | | | | | | | | |
| Sendelbach et al., (2015). Stop the Noise: A Quality Improvement Project to Decrease Electrocardiographic Nuisance Alarms. Critical Care Nurse. | N/A. | Quantitative performance improvement intervention | Sample: 16 bed adult ICU, pre & post measure of bundle interventions; Results: mean 28.5 alarms/ bed/day reduced to3.29, no change life threatening alarms, no change pulse ox alarms | Independent Variables: a bundled set of interventions that included deletion of duplicative alarms, customization of alarm status, daily ECG electrode changes, standardized skin preparation, and use of disposable ECG monitoring leads.<br><br>Dependent Variables: the number of alarms was reduced (3.29 total alarm signals per day per monitored bed, all of which were system alarms and alarms for life-threatening events). | Descriptive statistics were used to identify the changes over time. | Totals were calculated for the physiological alarm conditions and the system alarm conditions each week. The grand total of the summation of the alarm conditions was then divided by 7 (days in the week) to obtain the mean number of alarms per day. The mean number of alarms per day was then divided by the mean daily census for the patient care unit to obtain the rate per patient. | In this quality improvement project, we were able to demonstrate an 80% to 90% reduction in the number of nuisance ECG alarms in the CCU that has been sustained. After implementation of the quality improvement project, the alarm signals decreased to a low of 0.06 alarm signals per day per monitored bed, which is a 99.7% reduction. | Level IV | This was a quality improvement project, and we cannot establish a cause and effect relationship, that is, we cannot say that any one intervention resulted in more or less of a reduction in the number of nuisance alarm signals. In addition, the results are not generalizable. Another limitation is that we do not know the validity of the alarms that we still have, namely, the alarm signals for life-threatening events.] |
| **Article 5** | | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Lewandowska, Katarzyna, et al. "Impact of Alarm Fatigue on the Work of Nurses in an Intensive Care Environment—a Systematic review | N/A. | Systematic review-mixed method | Medical University in Gdansk, Poland Nurses in ICU N =356- nurses Quantitative Portion N =33- nurses Qualitative Portion. | Systematic Review – no variables Nurse perception of alarm fatigue and alarm exposure. Rating of 9 issues. | Quantity data were analyzed based on the HTF (Healthcare Technology Foundation) study. The importance of clinical alarms were assessed using a five-point Likert scale with nine positions and were calculated for the four articles (weighted average values). | Data were analyzed both descriptively and quantitatively, calculating a weighted average for specific synthetized data | Nurses from different parts of the world agree that burdensome alarms occur too frequently, disturb their care of patients, and reduce their trust in alarm systems. 93% of nurses, alarm fatigue may cause alarms to be excessively subdued or ignored. In the same study, as many as 81% of respondents stated that alarm fatigue results from the excessive number of false alarms. 52% of nurses do not know how to prevent alarm fatigue. Some of them declare that the only way is to adapt the alarms of devices showing patients' life parameters to their health condition. The number of nurses who thought that burdensome alarms are too frequent amounted to 81% in 2006, 76% in 2011, and 87% in 2016 | Level V | The main limitation of the study was its inability to pinpoint the type of fatigue caused by the alarms. There are no explicit literature records describing acute and chronic fatigue associated with alarms from monitoring devices. Another limitation was the small number of articles meeting the criteria, which forced the researchers to include both quantitative and quantitative studies in the review. |
| **Article 6** | | | | | | | | | |
| Graham, K. C., & Cvach, M. Monitor alarm fatigue: Standardizing use of physiological monitors and decreasing | N/A. | Descriptive pretest posttest Quality improvement project | ICU Sample 30 MPCU nurses Convenience sample Experimental group 30 MPCU nurses Control group None 30 in sample & 30 in experimental | Independent variables RN education: setting appropriate pt-specific VS parameters at the start of shift & troubleshooting different alarms<br><br>Dependent variable: number | None! Probably should have used an ANOVA determine causality based on 2 separate interventions (RN education & technology- | Patient were randomized each day and therefore, contributed data on multiple study days and possibly to both arms, violated the | Over the two-week study time frame, 22 unique patients were enrolled. There were 1,710 alarms over 163 hours of monitoring in the standard group and 1,165 alarms over 169 hours in the study group | Level V | This study had several potential This study had several potential limitations. First, the sample size was too small to draw conclusions about efficacy. This was not the intent of this study. Second, nurses were allowed to individualize alarms; therefore, deviation from study alarm parameters was possible. Nurses in the CCU typically customize alarms each shift, thus affecting one's ability to draw conclusions, but the |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| nuisance alarms . | | | | of crisis, warning, & system cardiac alarms.<br><br>Technology: widened MPCU default VS parameters & merged duplicate alarms generate 1 alarm for similar VS abnormalities | based interventions) . | independence assumption and necessitated the use of a multilevel regression analysis. To do this, two new variables were created: one unique for each study day and one unique for each patient. Using these two new variables, the alarm data were collapsed into study day–level data versus alarm-level data. | (P < 0.001). There were more CSEs detected (14 vs. 3) and ETIs (12 vs. 2) in the study group, | | current findings likely represent a more realistic assessment of the impact of altered<br>alarm settings<br>realistic assessment of the impact of altered<br>alarm settings |
| **Article 7** | | | | | | | | | |
| De Vaux et al., (2017). Reduction of Nonactionable Alarms in Medical Intensive Care. Biomed Instrum-Technol | NA | The authors used a prospective, pre/post-intervention design, and conducted the study in a medical ICU in an academic | Yale New Haven Hospital, York Street Campus. Two step-down units (28 beds each).<br><br>The unit has 130 nurses on staff and 56 beds (15 of which are | Independent Variable: reduction of sound exposure<br><br>Independent Variable: slow response on the part of the healthcare provider is dubbed ‘alarm | Two-part systematic review | Authors preformed different analyses for the 3 types of data: patient characteristics, alarms, and nurse surveys. | Total alarms decreased from 251 in March 2014 to 12 in February 2015. False alarms decreased from 201 in March 2014 to 12 in February 2015. | Level VI | This study had some limitations. First, this was a retrospective analysis of patients with both true and false alarms and did not include an examination of alarm fatigue or missed events. Therefore, the authors were unable to report whether true alarms were missed, clinical consequences to patients, or nurses’ responses to alarms. Second, the alarm data were collected from a single manufacturer and a single monitor platform. Nevertheless, the prevalence of false alarms, the fact that only a few |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | medical center. | considered "step-down" beds). There were 2 samples: patients and nurses. | fatigue',<br><br>Dependent Variable: improve the ICU environment. reduce patient exposure to bothersome alarms | | To compare patient characteristics before and after implementation of Alarm Advisor, the authors used the Wilcoxon-Mann-Whitney test for age and GCS and the chi-square test for gender and primary diagnosis. | | | patients are generally responsible for most alarms, and the need for algorithm improvement to reduce false alarms are issues relevant and applicable to critical care practice in general. Finally, our study included only 6 audible arrhythmias with low to high priority and did not include other types of alarms, such as premature ventricular contractions and parameter alarms (eg, heart rate too low or too high). |

N/A= Not Applicable

# Appendix E

## Critical Appraisal & Synthesis

**Table E1**

*Level of Evidence Synthesis*

| X (copy symbol as needed) | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **Level I: Systematic review or meta-analysis** | | | X | | | | |
| **Level II: Randomized controlled trial** | | X | | | | | |
| **Level III: Controlled trial without randomization** | | | X | | | | |
| **Level IV: Case-control or cohort study** | | | X | | | | |
| **Level V: Systematic review of qualitative or descriptive studies** | | X | | | | | |
| **Level VI: Qualitative or descriptive study, CPG, Lit Review, QI or EBP project** | X | | | | | | |
| **Level VII: Expert opinion** | | | X | | | | |

Legend: **1=** Nguyen et al.,2020. **2=** Bi et al., 2020. **3=** Lewis & Oster 2019. **4=** Baker & Rodger 2020. **5=** Lewandowski et al., 2020. **6=** Cvach et al., 2015., **7=** Burdick & Callahan 2020.

**Table E2**

*Outcome Synthesis*

| ↑, ↓, —, NE, NR, ✓ (select symbol and copy as needed) | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| **NFA** | ↓ | ✓ | ✓ | ↓ | **NR** | **NR** | ↓ |
| **AF** | ↓ | ↓ | ✓ | ↓ | ↓ | ↓ | ↓ |
| **IRT** | **NE** | ↑ | **NE** | **NE** | ↑ | ✓ | **NC** |
| **INS** | **NE** | **NE** | **NR** | ↓ | **NR** | ↓ | ↑ |
| **INPAF** | ↑ | ↑ | **NE** | **NR** | ↑ | ↑ | ↑ |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **DRA** | **NE** | **NE** | **NE** | ↓ | **NE** | **NE** | ↓ |
| | | | | | | | |

Symbol Key: ↑ = Increased, ↓ = Decreased, **—** = No Change, **NE** = Not Examined, **NR** = Not Reported (introduced at beginning but never reported at the end), ✓ = applicable or present

Abbreviations: **NFA** – Number of false alarms, **AF** – Alarm Fatigue, **IRT** – Improve response time, INS – Improve nurses satisfaction, **INPAF** – Improve nurses preception to alarm fatigue, **DRD** – Decrease risk for ICU-delirium

Legend **1=** Bi et al., 2020. **2**= Lewis & Oster 2019. **3**= Nguyen et al.,2020. **4=** Sendelbach et al., 2015. **5=** Lewandowski et al., 2020. **6=** Cvach et al., 2015. **7=** De Vaux et al (2017).

# Appendix F

Nursing Perception Towards False Alarms

## Table F1

*Nursing Survey Questionare*

| Statements | Agree or Strongly Agree | Neutral | Disagree or Strongly Disagree |
|---|---|---|---|
| **1) The purpose of clinical alarms is to alert staff of hazardous patient condition** | | | |
| **2) Alarm sounds and/or visual displays should differentiate alarm priority** | | | |
| **3) Alarm sounds and/or visual displays should be distinct based on source** | | | |
| **4) Alarms should affect multiple senses (audible, visual, proprioceptive, etc.)** | | | |
| **5) Nuisance alarms occur frequently** | | | |
| **6) Nuisance alarms disrupt patient care** | | | |
| **7) Nuisance alarms reduce trust in alarms and cause caregivers to turn them off** | | | |
| **8) The alarms used on my floor/area are adequate to alert staff** | | | |
| **9) There have been frequent instances where alarms could not be heard** | | | |
| **10) The staff is sensitive to alarms and responds quickly** | | | |
| **11) It can be confusing to determine which device is in alarm** | | | |

**Table F2**

*Nursing Survey Responses*

| **Questions*** | **Answers** | **Baseline** ***f*** **(%)** **n = 24** | **Week 6** ***f*** **(%)** **n = 24** | ***Week 12*** ***f*** **(%)** **n = 24** |
|---|---|---|---|---|
| *Question 1* | *Agree* | *13 (54.1)* | *16 (66.7)* | *19 (79.2)* |
| | *Neutral* | *7 (29.2)* | *7 (16.7)* | *5 (20.8)* |
| | *Disagree* | *4 (16.7)* | *3 (12.5)* | *0 (0.0)* |
| *Question 2* | *Agree* | *13 (54.1)* | *14 (58.3)* | *18 (75.0)* |
| | *Neutral* | *8 (33.3)* | *6 (25.0)* | *6 (25.0)* |
| | *Disagree* | *3 (12.5)* | *6 (25.0)* | *0 (0.0)* |
| *Question 3* | *Agree* | *9 (37.5)* | *17 (70.8)* | *20 (83.3)* |
| | *Neutral* | *10 (41.6)* | *7 (29.2)* | *4 (16.7)* |
| | *Disagree* | *5 (20.8)* | *0 (0.0)* | *0 (0.0)* |
| *Question 4* | *Agree* | *11 (45.8)* | *17 (70.8)* | *12 (50.0)* |
| | *Neutral* | *9 (37.5)* | *7 (29.2)* | *8 (33.3)* |
| | *Disagree* | *4 (16.7)* | *0 (0.0)* | *4 (16.7)* |
| *Question 5* | *Agree* | *16 (6.6)* | *17 (70.8)* | *16 (66.7)* |
| | *Neutral* | *5 (20.8)* | *6 (25.8)* | *6 (25.0)* |
| | *Disagree* | *3 (12.5)* | *3 (4.2)* | *2 (8.3)* |
| *Question 6* | *Agree* | *13 (54.1)* | *18 (75.0)* | *16 (66.7)* |
| | *Neutral* | *9 (37.5)* | *4 (16.7)* | *6 (25.0)* |
| | *Disagree* | *2 (8.3)* | *4 (8.3)* | *2 (8.3)* |
| *Question 7* | *Agree* | *12 (50.0)* | *14 (70.8)* | *17 (70.8)* |
| | *Neutral* | *7 (29.1)* | *4 (16.7)* | *3 (12.5)* |
| | *Disagree* | *5 (20.9)* | *8 (4.2)* | *4 (16.7)* |
| *Question 8* | *Agree* | *13(54.2)* | *14 (58.3)* | *14 (58.3)* |
| | *Neutral* | *9 (37.5)* | *6 (25.0)* | *6 (25.0)* |
| | *Disagree* | *2(8.3)* | *6 (25.0)* | *4 (16.7)* |
| *Question 9* | *Agree* | *11(45.8)* | *12 (50.0)* | *12 (50.0)* |
| | *Neutral* | *8 (33.3* | *8 (33.3)* | *6 (25.0)* |
| | *Disagree* | *5 (20.8)* | *6 (25.0)* | *6 (25.0)* |
| *Question 10* | *Agree* | *11 (45.8)* | *15 (66.7)* | *16 (66.7)* |
| | *Neutral* | *9 (37.5)* | *4 (29.2)* | *6 (25.0)* |
| | *Disagree* | *4 (16.7)* | *7 (4.2)* | *2 (8.3)* |
| *Question 11* | *Agree* | *4(16.7)* | *10 (75.0)* | *17 (70.8)* |
| | *Neutral* | *9 (37.5)* | *6 (8.3)* | *3 (12.5)* |
| | *Disagree* | *11 (45.8)* | *6 (8.3)* | *4 (6.7)* |

***n****=total number of nurses who completed survey;* ***f****=number of answers;* ***%****=percentage of satisfaction (****f/n*** *x 100)*

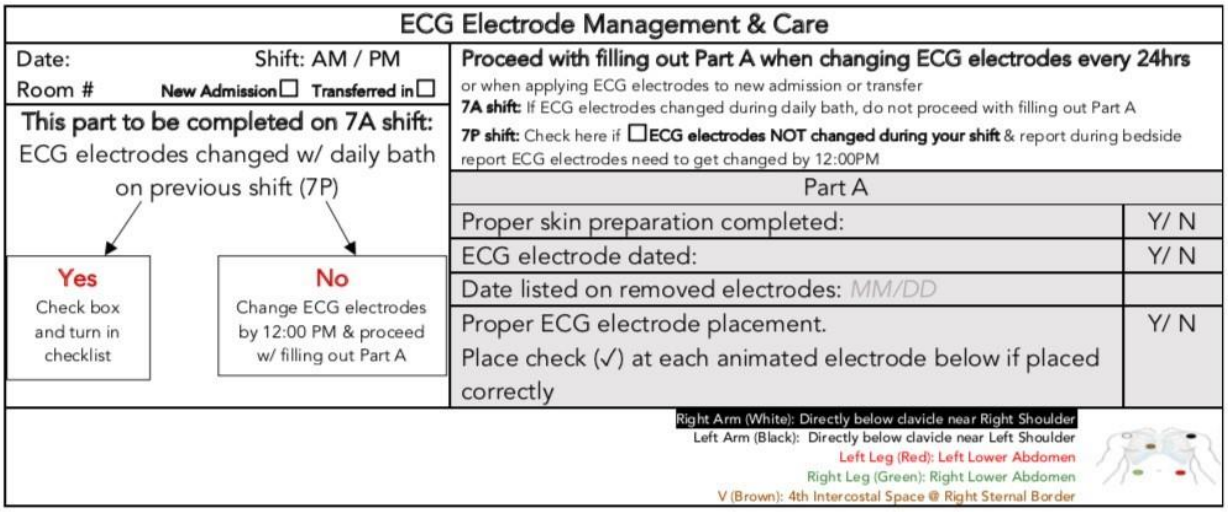
**Detail of questions refer to Table E1 above*

# Appendix G

Alarm Bundle Checklist

**Figure 5**

*ECG Electrode Management & Care Form*



ECG Electrode Management & Care

Date: Shift: AM / PM

Room # New Admission☐ Transferred in☐

This part to be completed on 7A shift:

ECG electrodes changed w/ daily bath on previous shift (7P)

Yes
Check box and turn in checklist

No
Change ECG electrodes by 12:00 PM & proceed w/ filling out Part A

**Proceed with filling out Part A when changing ECG electrodes every 24hrs**
or when applying ECG electrodes to new admission or transfer
**7A shift:** If ECG electrodes changed during daily bath, do not proceed with filling out Part A
**7P shift:** Check here if ☐**ECG electrodes NOT changed during your shift** & report during bedside report ECG electrodes need to get changed by 12:00PM

| Part A | |
|---|---|
| Proper skin preparation completed: | Y/ N |
| ECG electrode dated: | Y/ N |
| Date listed on removed electrodes: MM/DD | |
| Proper ECG electrode placement. Place check (✓) at each animated electrode below if placed correctly | Y/ N |

Right Arm (White): Directly below clavicle near Right Shoulder
Left Arm (Black): Directly below clavicle near Left Shoulder
Left Leg (Red): Left Lower Abdomen
Right Leg (Green): Right Lower Abdomen
V (Brown): 4th Intercostal Space @ Right Sternal Border

**Table G1**

*Documentation of EMC Forms and Unit Alarms*

| | ***n*** | ***f*** | ***%*** | | |
|---|---|---|---|---|---|
| *Documentation*:* | | | | | |
| *Week 1* | *NA* | *NA* | *NA* | | |
| *Week 2* | *NA* | *NA* | *NA* | | |
| *Week 3* | *NA* | *NA* | *NA* | | |
| *Week 4* | *NA* | *NA* | *NA* | | |
| *Week 5* | *NA* | *NA* | *NA* | | |
| *Week 6* | *NA* | *NA* | *NA* | | |
| *Week 7* | *13* | *12* | *92.3* | | |
| *Week 8* | *12* | *11* | *91.7* | | |
| *Week 9* | *8* | *8* | *100.0* | | |
| *Week 10* | *11* | *10* | *90.9* | | |
| *Week 11* | *10* | *9* | *90.0* | | |
| *Week 12* | *13* | *11* | *84.6* | | |
| *Alarms**:* | ***n*** | ***f*$^{1}$** | ***f*$^{2}$** | ***f*$^{3}$** | ***%*** |
| *Week 1* | *121* | *3* | *33* | *54* | *44.6* |
| *Week 2* | *130* | *27* | *51* | *52* | *40.0* |
| *Week 3* | *151* | *29* | *52* | *70* | *46.3* |
| *Week 4* | *113* | *30* | *32* | *51* | *44.0* |
| *Week 5* | *161* | *49* | *40* | *72* | *44.7* |
| *Week 6* | *131* | *30* | *42* | *59* | *45.0* |
| *Week 7* | *118* | *33* | *35* | *50* | *42.3* |
| *Week 8* | *127* | *22* | *49* | *56* | *44.0* |
| *Week 9* | *107* | *34* | *29* | *44* | *41.0* |
| *Week 10* | *125* | *28* | *45* | *52* | *42.0* |
| *Week 11* | *132* | *36* | *41* | *55* | *41.6* |
| *Week 12* | *128* | *39* | *36* | *53* | *41.4* |

****n***=total number of patients on unit; ***f***=number of completed documentation form; ***%*=**percentage of documentation completion (***f*/*n*** x 100); NA=no data

** ***n*=**-number of all alarms (atrial + ventricular + false); ***f*$^{1}$**=number of atrial alarms; ***f*$^{2}$**=number of ventricular; ***f*$^{3}$**=-number of false alarm; ***%*=**percentage of false alarm (***f*$^{3}$/*n*** x 100).

# Appendix H

Teaching Plan for Alarm Bundle Implementation Project

## Table H1

*Alarm Management Protocol*

| | **Education:** | **Alarm Rate Perception Survey** | **Daily skincare & ECG electrode change documentation form** | **Alarm Rate (real & false) documentation Form** |
|---|---|---|---|---|
| | | **Time spent in hrs.** | | |
| *Week 1* | 5 | 3 | | 2 |
| *Week 2* | | | | 2 |
| *Week 3* | | | | 2 |
| *Week 4* | | | | 2 |
| *Week 5* | | | | 2 |
| *Week 6* | 5 | 3 | | 2 |
| *Week 7* | | | 3 | 3 |
| *Week 8* | | | 3 | 3 |
| *Week 9* | 3 | | 3 | 3 |
| *Week 10* | | | 3 | 3 |
| *Week 11* | | | 3 | 3 |
| *Week 12* | | 3 | 3 | 3 |

# Appendix I

**Table I1**

*Final Project Cost*

| | |
|---|---|
| **Estimated Project Cost** | |
| **Project Leader Time**<br>4.2% of average ICU RN annual salary $ 88,782. | $3755.84 |
| Nursing Education Presentation<br>Coffee & Breakfast | $48.00 |
| Nursing Education Presentation<br>Afternoon Snacks | $35.00 |
| Nursing Education Presentation<br>Unit Celebration & Acknowledgments | $75.00 |
| Custom Pocket Guides (alarm bundle checklist) x 20 colored; cost of paper to supply nursing survey and EMC forms. | $60.00 |
| **Total Cost** | $3973.84 |

# Appendix J

## Executive Summary

In the critical care unit, exposure to frequent cardiac false alarm rhythms can lead to sensory overload and delayed reaction (aka, alarm fatigue). Patients are at risk because staff may eventually ignore all alarm sounds, even true ones. An alarm bundle checklist that includes daily skin cleansing with soap, water and change of ECG electrodes will reduce alarm fatigue and increase patient and staff satisfaction. The goal of this QI project is to establish alarm management protocol at GH.

This QI project used the Model for Improvement (MFI) (IHI, 2023) to guide the implementation. The MFI utilizes cycles of the Plan-Do-Study-Act (PDSA). These PSDA cycles allowed the QI team to adapt to changes in the real work setting. Outcome goals were to see a reduction in false alarms, track adherence to the alarm bundle checklist, and see improvement in nursing perception of alarm fatigue in the ICU. The study occurred over 12 weeks. A total 1,544 cardiac rhythms were recorded based on atrial, ventricular, and false rhythms. The occurrence of false alarms prior to the alarm bundle checklist was 44.3% (2) with a 2.3% reduction after the implementation of the alarm bundle checklist at 42% (1). The alarm bundle adherence showed >90% completion rate except for last week of the study, which decreased to 86%. Overall, responses (n=24) to the 11-question nursing survey showed >10% improvement by week 12 except for the question that directly asked about the occurrence of nuisance alarms, which did not change from baseline to end of study.

Barriers that occurred during implementation included lack of time to complete the alarm bundle checklist form and staff turnover. Therefore, having more PDSA cycles may show larger reduction in false cardiac rhythm rates and improve sustainability of alarm management

protocol. In summary, establishing an alarm management protocol contributes to a safe environment for ICU patients and staff.