Improving Patient Safety by Reducing Nurses' Alarm Fatigue

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The Emergency Care Research Institute (ECRI, 2023) report, *Top 10 Patient Safety Concerns 2023*, identifies "preventable harm due to omitted care or treatment" as one of its top safety concerns. The report lists various reasons for omitted care or treatment, such as "inadequate staffing levels; increased workload [such as increased monitoring alarms]; poor work environment; limited staff experience, education [on alarm management], or competency; lack of material resources; poor communication; poor care transitions; limited skills mix of staff on the unit; and lack of teamwork." Alarm fatigue was defined by Lewandowska, et al. (2020) as "an excessive exposure to the stimulus generated by the monitoring unit… [leading to] lack of energy to act." In 2020, ECRI described alarm hazards as "the lack of adequate reaction to an alarm and poor management of alarms or their settings (ECRI, 2020). If alarms are ignored or missed due to alarm fatigue related to faulty or excessive monitoring alarms in the intensive care unit nurses may fail to provide timely or proper care leading to patient safety issues.

This paper addresses the PICOT question in neonatal intensive care patients (P), how does implementing the CEASE bundle (Communication, Electrodes, Appropriateness, Setup, and Education) (I) compared to standard practice (C) affect nurses' perception of alarm fatigue (O) within 3 months, 6 months, and 12 months (T)? A related outcome measure might address the effects on the number of patient safety issues during the same period. The objective of the inquiry is to identify best nursing practices for improving patient safety by reducing nurses' alarm fatigue in the NICU. A brief literature review was conducted to clarify the problem and to find possible solutions.

Alarm fatigue was generally agreed to be a significant patient safety hazard and the CEASE bundle was identified as a possible clinical intervention and best practice to improve

safety. The bundle was developed in 2013 in response to an increasing number of alarms in critical care settings (AACN, 2013). The CEASE bundle has since been implemented in several critical care units (AACN, 2023) and was reported to result "in improved alarm management competency, decreased alarm fatigue, and positive changes in nursing practice." Several different quality measures, such as surveys, alarm frequency, and time to respond, were used in the studies to evaluate the effects of interventions on alarm fatigue (Bi & Yin, 2020, Bosma & Christopher, 2023, Jeong & Kim., 2023, Lewandowska, et al., 2020). This paper will also recommend a survey instrument to assess nurses' alarm fatigue.

Literature Review

Bi and Yin (2020) reported on a single-blind trial investigation of the effectiveness of alarm management training on reducing nurses' alarm fatigue in an intensive care unit (ICU). The authors studied the alarm fatigue of 93 nurses, 47 in the experimental group and 46 in the control group, in a busy ICU. The experimental group received alarm management training that was found to effectively decrease alarm fatigue versus the control group (who did not receive training). It is worth noting that alarm management training is one of the components of the CEASE bundle discussed below.

Jeong and Kim (2023) used self-administered questionnaires to evaluate the level and causes of alarm fatigue among 48 nurses. The nurses complained that "frequent false alarms… lead to reduced attention or response to alarms." The nurses also expressed that "inadequate staffing" contributed to slow alarm responses. The authors made two main recommendations. First, health systems should "develop a standardized medical device alarm management protocol" that includes training for nurses. The authors also recommend "employment of

sufficient nursing personnel in ICUs." This was a limited study in one hospital and it may not be possible to generalize the results.

Lewandowska et al. (2020), in a systematic review of seven selected studies on nurses' alarm fatigue (a total of 389 nurses) found five studies that used the Healthcare Technology Foundation questionnaire to evaluate nurses' alarm fatigue. The authors reported that false or clinically insignificant alarms may "amount to 85 – 99% of all alarms." The average number of alarms per ICU *patient* per *shift* has increased from about 6 alarms/patient/shift forty years ago to 150 – 400 alarms/*patient*/*shift*. One of the reports included in the review found that the nurses lacked training on basic cardiac monitor functions. The critical care nurses found the number of alarms burdensome, identified that the alarms interfered with patient care, and caused reduced trust in the alarms. The authors of the systematic review concluded that alarm fatigue may have serious consequences for patients and nurses. They recommend using a strategy of alarm management and ongoing measurement of nurses' alarm fatigue, though none of the interventions reported included long-term measurement. The review includes recommendations from the American Association of Critical Care Nurses (AACN) introduced in 2013. AACN recommended a combination of strategies to mitigate the effects of alarm fatigue, including training, suitable skin preparation before applying sensors, changing pulse oximeter sensors regularly, and having a team responsible for the alarm system. As discussed below, these recommendations were later incorporated into the CEASE bundle. The review authors concluded that "nurses are exposed to too many false alarms and are overwhelmed by the introduction of new technologies."

Lewis and Osler (2019) reported on their implementation of the CEASE bundle in a thirty-six-bed ICU. The purpose of the CEASE bundle is to reduce nurses' alarm fatigue and

prevent possible adverse events due to alarm fatigue. Table 1 summarizes the elements of the bundle; the elements are discussed in detail below. Lewis and Osler define alarm fatigue as "the lack of response due to excessive numbers of alarms resulting in overload and desensitization." There is only limited data available about how often the CEASE bundle has been implemented. This report concerns an exploratory, nonrandomized test with 74 nurses. There were 35 nurses in the pre-implementation test group and, 30 days later, 18 nurses in the post-implementation test group. The authors do not account for the drop-outs. No adverse alarm events occurred during the study. Both pre-and post-test groups completed the Healthcare Technology Foundation Clinical Alarms Survey, similar to the survey instrument used by other researchers. This is a validated instrument available in numerous languages (Alsuyayfi & Alanazi, 2022).

The impetus for developing the CEASE bundle was a Sentinel Event Alert from the Joint Commission (Mitka, 2013) that reviewed 98 alarm-related events that resulted in 80 deaths, 13 patients with permanent loss of function, and 5 unexpected delays in stay. The results from Lewis and Osler's (2019) limited study were that the total number of alarms decreased by 30 – 45% following bundle implementation. The nurses perceived a significant decrease in nuisance alarms. The authors concluded that the results "suggest that the CEASE Bundle is an effective alarm intervention to reduce the number of clinical alarms in an ICU/SCU setting without compromising patient safety."

Shih, Lee, and Mills (2022) studied nurses' perceptions of the effects of alarm management on their practice. The authors used focus group interviews to conduct the investigation. They found that nurse management of alarm settings was influenced by their knowledge and experience. The authors suggest that nurse alarm management may be enhanced by training, valuing patient-centered care, and wireless technology.

Solution Description

The literature review identified several possible solutions to the problem of nurses' alarm fatigue in critical care. Some single interventions, such as alarm management training (Bi and Yin, 2020, Shih, Lee, and Mills, 2022), were suggested by multiple authors. Reports of CEASE bundle implementation from Lewandowska et al. (2020) and Lewis and Osler (2019) influenced this choice to recommend the bundle, which includes alarm management training and additional interventions. Although, as noted in the literature review, there were limitations in the review by Lewandowska et al. (2020) and the implementation study by Lewis and Osler (2019), the CEASE bundle remains the only comprehensive solution identified. It has been selected as the intervention to implement in the NICU for this hospital. The Healthcare Technology Foundation questionnaire to evaluate nurses' alarm fatigue has been selected as the validated evaluation instrument, to be used in before and after implementation testing. The test period will last 90 days with an extended follow-up period of 12 months.

The CEASE bundle includes multiple components, as follows. The first component is communication (C) with colleagues to ensure all care providers are using the bundle correctly and effectively. The next component is to provide proper skin preparation before applying heart monitor and pulse oximeter electrodes (E); change them daily and as needed. Use appropriate (A) interprofessional collaboration to ensure proper orders with monitoring parameters and discontinuation orders are in place; discontinue monitoring as soon as possible. Use customized set up (S) of alarm parameters for each patient except for alarms for ventricular tachycardia, ventricular fibrillation, and asystole (set these per institution policy). The final component is to educate (E) the providers and staff on alarm system management and protocols.

Implementation of the CEASE bundle has implications for patients, healthcare providers, and hospitals. Fewer alarms in the NICU should reduce the noise in the environment, creating a safer, quieter environment for patients because "noise [in the NICU] may cause apnea, hypoxemia, alternation in oxygen saturation, and increased oxygen consumption secondary to elevated heart and respiratory rates (Almadhoob & Ohlsson, 2020). Improved patient safety should result from reduced false and/or ignored alarms (Jeong and Kim, 2023, Lewis and Osler, 2019). In addition to nurses, healthcare providers may be included in the alarm management training to promote interprofessional communication and collaboration and ensure orders are consistent. There are no new equipment expenses, but the hospital will have to manage scheduling (for training and clinical coverage) and will incur additional expenses for time for training everyone involved. The hospital may save money if implementing the CEASE bundle reduces nurse turnover. The overall goal of this evidence-based practice change is to improve patient safety by reducing nurses' alarm fatigue.

Failure Mode and Effect Analysis

Notes on the NICU environment – To understand some of the failure modes, it is helpful to have an understanding of a typical NICU environment. NICUs may be one large room with all the babies in it or may be organized in pods with about four babies per pod. Since this is critical care, there are frequent patient emergencies, especially respiratory emergencies. The patients' conditions are frequently unstable. When there is an emergency in the room or pod, there can be a lot of noise and commotion in the area. Micro-preemies, those delivered at 23 – 27 weeks gestation, have extremely delicate skin and have to be maintained in a very high humidity environment incubator which keeps their skin very moist. These two things make it difficult to prep the skin correctly or to keep the sensors attached.

Refer to Table 1 to see the CEASE bundle checklist where process steps are described in more detail. Figure 1 presents the CEASE bundle workflow and process steps. The Failure Mode Effects analysis of 5 of the process steps is presented below.

	1	Process Step	**Screen patient's monitoring needs[1].**		
Process Step #1	2	Potential Failure Mode	Patient Emergency	Missing or incomplete orders	VS unstable
	3	Potential Cause(s)	High acuity patients	Provider order sets incomplete? Gap in communication?	High acuity patients
	4	Severity [R/T screening, not patient condition]	Minor event	Minor event	Minor event
	5	Probability [of potential failure at this step]	Frequent	Uncommon	Frequent
	6	Hazard Score	4	4	4
	7	Action (Eliminate, Control, or Accept)	Accept	Eliminate	Accept
	8	Description of Action	Minor event, accept r/t patient conditions	Review/revise order sets and communication protocols.	Minor event, accept r/t patient conditions

[1]One of the components of the CEASE bundle is training on alarm management. This would entail setting up new order sets to allow nurses to adjust monitor settings except those that are excluded (alarms for asystole, VFIB, and VTACH).

	1	**Process Step**	**Adjust monitor settings per protocol[2].**		
Process Step #2	2	Potential Failure Mode	Missing or incomplete orders	Defective monitor	Sensor problems or failure
	3	Potential Cause(s)	Provider order sets incomplete? Lack of provider training?	Hardware or software failure	Low-quality sensors or incorrect skin prep
	4	Severity	Moderate	Moderate	Moderate
	5	Probability	Uncommon [after new protocol implementation]	Remote	Occasional [after new protocol implementation]
	6	Hazard Score	4	2	3
	7	Action (Eliminate, Control, or Accept)	Eliminate	Control	Eliminate
	8	Description of Action	Train providers on new protocol (+ ongoing training for new providers)	Routine maintenance and testing. Immediately remove and replace defective equipment.	Train nurses on new protocol (+ ongoing training for new nurses). Use high-quality sensors.

[2]One of the components of the CEASE bundle is training on alarm management and monitor use.

Process Step #3	1	Process Step	**Communicate and/or suspend alarms during care[3].**		
	2	Potential Failure Mode	Patient emergency	Interference w/ communication (other emergency, noise, etc.)	Nurse forgot to suspend alarms during cares
	3	Potential Cause(s)	High acuity patients	Noise and confusion in NICU	Operator training failure
	4	Severity	Minor	Minor	Minor
	5	Probability	Occasional	Occasional	Occasional
	6	Hazard Score	3	3	3
	7	Action (Eliminate, Control, or Accept)	Control	Control	Eliminate
	8	Description of Action	CEASE bundle nurse training	Reduce noise in NICU (R/T other protocols for noise reduction)	CEASE bundle nurse training

[3]One of the components of the CEASE bundle is to suspend alarms when providing routine cares to eliminate false alarms.

	1	Process Step	**Change and place electrodes per CEASE protocol.[4]**		
Process Step #4	2	Potential Failure Mode	New electrodes or supplies not available	Skin breakdown or fragility at application site(s)	High humidity environment (e.g. micro-preemie in incubator)
	3	Potential Cause(s)	Stocking error or par set too low	Difficult to prep skin at correct location	Difficult to dry skin
	4	Severity	Moderate	Moderate	Moderate
	5	Probability	Occasional	Occasional	Frequent
	6	Hazard Score	6	6	8
	7	Action (Eliminate, Control, or Accept)	Control	Control	Control
	8	Description of Action	Adjust par levels and assign nurse to monitor inventory	CEASE bundle[5] nurse training	CEASE bundle nurse training

[4]One of the components of the CEASE bundle is proper preparation for and placement of electrodes.

Process Step #5	1	Process Step	**Arrange additional training if needed.**[5]		
	2	Potential Failure Mode	No training available	Scheduling conflict	No Internet access (for online training from remote location)
	3	Potential Cause(s)	Lack of planning	Lack of planning	Nurses and providers training from home
	4	Severity	Minor	Minor	Minor
	5	Probability	Uncommon	Uncommon	Uncommon
	6	Hazard Score	2	2	2
	7	Action (Eliminate, Control, or Accept)	Control	Control	Eliminate
	8	Description of Action	Initial training[2], regular planning for training for new nurses and for refresher courses.	Initial training, regular planning for training for new nurses, and for refresher courses.	No training from home per HR.

[5]One of the components of the CEASE bundle is training on alarm management and monitor use.

Table 1

CEASE bundle checklist

The Step column in the checklist refers to the process steps discussed above.

Step	Title		Yes	No
3	Communication			
		Communicate and/or suspend alarms when performing care activities that create non-actionable alarms		
4	Electrodes			
		Change ECG electrodes and place appropriately		
		Clip excessive hair. Clean skin and dry with towel before placing electrodes.		
		Check skin under pulse oximetry sensor and change as needed.		
1	Appropriate			
		Screen patient to determine if appropriate for monitoring.		
		Discontinue monitoring when no longer needed.		
2	Setup			
		Customize alarm parameters +/- 10% patient baseline within 1 hour assuming care		
		Customize alarm parameters +/- 10% patient baseline when patient condition changes.		
5	Education			
		More training on evidence-based monitoring needed?		

Figure 1

CEASE bundle workflow

CEASE Bundle Workflow
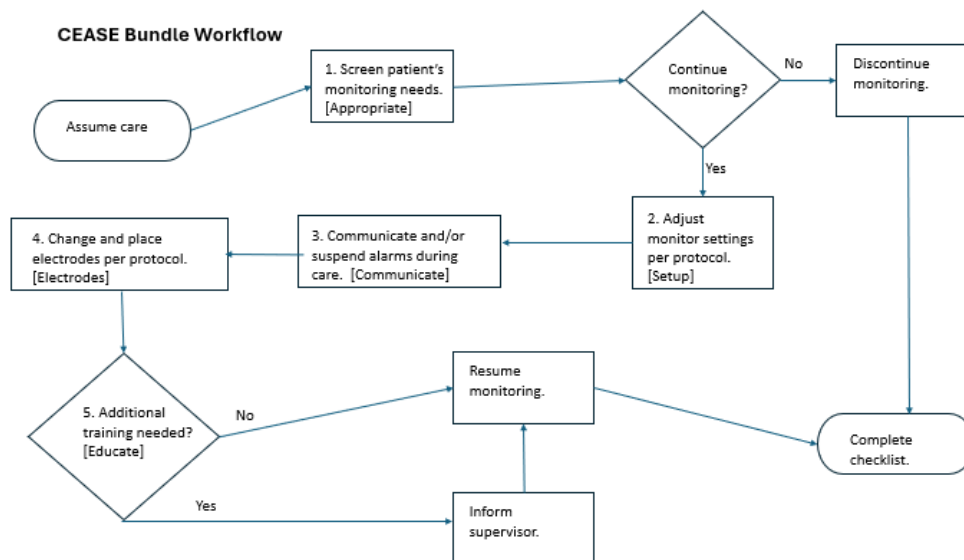
Quality Measurement Plan

As discussed above, the connection between nurses' alarm fatigue and patient safety has been established. This paper has identified a recommended evidence-based practice solution to reducing nurses' alarm fatigue to increase patient safety -- implementation of the CEASE bundle. Several authors used the Healthcare Technology Foundation Clinical Alarms Survey to evaluate the efficacy of alarm fatigue reduction interventions. This is a validated survey instrument available in several languages. For this evidence-based practice implementation, the Healthcare Technology Foundation Clinical Alarms Survey, similar to the survey instrument used by Alsuyayfi and Alanazi (2022) is the recommended quality measure. Refer to Appendix A for the list of questions used in the survey. Lewis and Osler (2019) reported a 30 – 45% reduction in nurses' perceived alarm fatigue post-intervention. For this implementation of the CEASE bundle,

we also anticipate a 30 – 45% reduction. This goal may be revised after reviewing and comparing data from the pre-intervention survey to the results reported by others.

The weaknesses of several of the studies reviewed were attributed to a lack of long-term follow-up. For this implementation, the implementation team will evaluate nurses' perceived alarm fatigue by surveys at 90 days, 6 months, and 12 months to better evaluate the long-term effects of the intervention. Following each evaluation, the team will review the need to modify the bundle. The survey responses will be collected online, through a web-based application (Survey Monkey) to assure subject anonymity. All nurses on the NICU staff have access to this app during working hours.

Conclusion

This paper addressed the question in neonatal intensive care patients, how does implementing the CEASE bundle compared to standard practice affect nurses' perception of alarm fatigue within 3 months, 6 months, and 12 months? The objective of the inquiry was to identify best nursing practices for improving patient safety by reducing nurses' alarm fatigue in the NICU. A brief literature review was conducted to clarify the problem and to find possible solutions. Alarm fatigue was generally agreed to be a significant patient safety hazard. The CEASE bundle was identified as a clinical intervention and best practice to decrease alarm fatigue. The implementation solution includes a validated survey instrument for measuring nurses' alarm fatigue.

The links between nurses' alarm fatigue and alarm responses have been established. More research is needed to firmly establish the connection between CEASE bundle implementation, alarm fatigue, and *measurable improvements in patient safety*. Improvements in patient safety might be measured by monitoring and review of electronic health records,

documented use of standardized checklists, measurement of missed nursing care, time to alarm response, adverse event reporting, and root cause analysis. The NICU where this CEASE bundle implementation is planned might be a location for additional research on related patient safety outcomes.

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    5&db=rzh

Appendix 1

Healthcare Technology Foundation clinical alarms survey suestions

(Alsuyayfi &Alanazi, 2022)

Respondents answer each question by a 5-point Likert scale or a yes/no answer.

1. Alarm sounds and/or visual displays should differentiate the priority of alarm.

2. Alarm sounds and/or visual displays should be distinct based on the parameter (e.g., heart rate) or source (device type).

3. Nuisance alarms occur frequently.

4. Nuisance alarms disrupt patient care.

5. Nuisance alarms reduce trust in alarms and cause caregivers to inappropriately turn alarms off at times other than setup or procedural events.

6. Properly setting alarm parameters and alerts is overly complex in existing devices.

7. Newer monitoring systems (e.g. <3 years old) have solved most of the previous problems we experienced with clinical alarms.

8. The alarms used on my floor/area of the hospital are adequate to alert staff of potential or actual changes in a patient's condition.

9. There have been frequent instances where alarms could not be heard and were missed.

10. Clinical staff are sensitive to alarms and responds quickly.

11. The medical devices used on my unit/floor all have distinct outputs (i.e., sounds, repetition rates, visual displays, etc.) that allow users to identify the source of the alarm.

12. When a number of devices are used with a patient, it can be confusing to determine which device is in an alarm condition.

13. Environmental background noise has interfered with alarm recognition.

14. Central alarm management staff responsible for receiving alarm messages and alerting appropriate staff is helpful.

15. Alarm integration and communication systems via pagers, cell phones, and other wireless devices are useful for improving alarm management and response.

16. Smart alarms (e.g., where multiple parameters, rate of change parameters, and signal quality are automatically assessed in their entirety) would be effective to use for reducing false alarms.

17. Smart alarms (e.g., where multiple parameters, rate of change of parameters, and signal quality are automatically assessed in their entirety) would be effective to use for improving clinical response to important patient alarms.

18. Clinical policies and procedures regarding alarm management are effectively used in my facility.

19. There is a requirement in your institution to document that the alarms are set and are appropriate for each patient.