

Impact of a Safety Huddle–Based Intervention on Monitor Alarm Rates in Low-Acuity Pediatric Intensive Care Unit Patients

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BACKGROUND: Physiologic monitors generate high rates of alarms in the pediatric intensive care unit (PICU), yet few are actionable.

OBJECTIVE: To determine the association between a huddle-based intervention focused on reducing unnecessary alarms and the change in individual patients' alarm rates in the 24 hours after huddles.

DESIGN: Quasi-experimental study with concurrent and historical controls.

SETTING: A 55-bed PICU.

PARTICIPANTS: Three hundred low-acuity patients with more than 40 alarms during the 4 hours preceding a safety huddle in the PICU between April 1, 2015, and October 31, 2015.

INTERVENTION: Structured safety huddle review and discussion of alarm causes and possible monitor parameter adjustments to reduce unnecessary alarms.

MAIN MEASUREMENTS: Rate of priority alarms per 24 hours occurring for intervention patients as compared with concurrent and historical controls. Balancing measures included unexpected changes in patient acuity and code blue events.

RESULTS: Clinicians adjusted alarm parameters in the 5 hours following the huddles in 42% of intervention patients compared with 24% of control patients ($P = .002$). The estimate of the effect of the intervention adjusted for age and sex compared with concurrent controls was a reduction of 116 priority alarms (95% confidence interval, 37-194) per 24 hours ($P = .004$). There were no unexpected changes in patient acuity or code blue events related to the intervention.

CONCLUSION: Integrating a data-driven monitor alarm discussion into safety huddles was a safe and effective approach to reducing alarms in low-acuity, high-alarm PICU patients. *Journal of Hospital Medicine* 2017;12:652-657. © 2017 Society of Hospital Medicine

BACKGROUND

Physiologic monitors are intended to prevent cardiac and respiratory arrest by generating alarms to alert clinicians to signs of instability. To minimize the probability that monitors will miss signs of deterioration, alarm algorithms and default parameters are often set to maximize sensitivity while sacrificing specificity.¹ As a result, monitors generate large numbers of nonactionable alarms—alarms that are either invalid and do not accurately represent the physiologic status of the patient or are valid but do not warrant clinical intervention.² Prior research has demonstrated that the pediatric intensive care unit (PICU) is responsible for a higher proportion of alarms than pediatric wards³ and a large proportion of these alarms, 87% - 97%, are nonactionable.⁴⁻⁸ In national surveys of healthcare staff, respondents report that high alarm rates interrupt patient care and can lead clinicians to disable alarms entirely.⁹ Recent research has supported this, demonstrating that nurses who are exposed

to higher numbers of alarms have slower response times to alarms.^{4,10} In an attempt to mitigate safety risks, the Joint Commission in 2012 issued recommendations for hospitals to (a) establish guidelines for tailoring alarm settings and limits for individual patients and (b) identify situations in which alarms are not clinically necessary.¹¹

In order to address these recommendations within our PICU, we sought to evaluate the impact of a focused physiologic monitor alarm reduction intervention integrated into safety huddles. Safety huddles are brief, structured discussions among physicians, nurses, and other staff aiming to identify safety concerns.¹² Huddles offer an appropriate forum for reviewing alarm data and identifying patients whose high alarm rates may necessitate safe tailoring of alarm limits. Pilot data demonstrating high alarm rates among low-acuity PICU patients led us to hypothesize that low-acuity, high-alarm PICU patients would be a safe and effective target for an alarm huddle-based intervention.

In this study, we aimed to measure the impact of a structured safety huddle review of low-acuity PICU patients with high rates of priority alarms who were randomized to intervention compared with other low-acuity, high-alarm, concurrent, and historical control patients in the PICU.

METHODS

Study Definitions

Priority alarm activation rate. We conceptualized priority alarms as any alarm for a clinical condition that requires a timely response to determine if intervention is necessary to save a patient's life,⁴ yet little empirical data support its

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existence in the hospital. We operationally defined these alarms on the General Electric Solar physiologic monitoring devices as any potentially life-threatening events including lethal arrhythmias (asystole, ventricular tachycardia, and ventricular fibrillation) and alarms for vital signs (heart rate, respiratory rate, and oxygen saturation) outside of the set parameter limits. These alarms produced audible tones in the patient room and automatically sent text messages to the nurse's phone and had the potential to contribute to alarm fatigue regardless of the nurse's location.

High-alarm patients. High-alarm patients were those who had more than 40 priority alarms in the preceding 4 hours, representing the top 20% of alarm rates in the PICU according to prior quality improvement projects completed in our PICU.

Low-acuity patients. Prior to and during this study, patient acuity was determined using the OptiLink Patient Classification System (OptiLink Healthcare Management Systems, Inc.; Tigard, OR; www.optilinkhealthcare.com; see Appendix 1) for the PICU twice daily. Low-acuity patients comprised on average 16% of the PICU patients.

Setting and Subjects

This study was performed in the PICU at The Children's Hospital of Philadelphia.

The PICU is made up of 3 separate wings: east, south, and west. Bed availability was the only factor determining patient placement on the east, south, or west wing; the physical bed location was not preferentially assigned based on diagnosis or disease severity. The east wing was the intervention unit where the huddles occurred.

The PICU is composed of 3 different geographical teams. Two of the teams are composed of 4 to 5 pediatric or emergency medicine residents, 1 fellow, and 1 attending covering the south and west wings. The third team, located on the east wing, is composed of 1 to 2 pediatric residents, 2 to 3 nurse practitioners, 1 fellow, and 1 attending. Bedside family-centered rounds are held at each patient room, with the bedside nurse participating by reading a nursing rounding script that includes vital signs, vascular access, continuous medications, and additional questions or concerns.

Control subjects were any monitored patients on any of the 3 wings of the PICU between April 1, 2015, and October 31, 2015. The control patients were in 2 categories: historical controls from April 1, 2015, to May 31, 2015, and concurrent controls from June 1, 2015, to October 31, 2015, who were located anywhere in the PICU. On each nonholiday weekday beginning June 1, 2015, we randomly selected up to 2 patients to receive the intervention. These were high-alarm, low-acuity patients on the east wing to be discussed in the daily morning huddle. If more than 2 high-alarm, low-acuity patients were eligible for intervention, they were randomly selected by using the RAND function in Microsoft Excel. The other low-acuity, high-alarm patients in the PICU were included as control patients. Patients were eligible for the study if they were present for the 4 hours

prior to huddle and present past noon on the day of huddle. If patients met criteria as high-alarm, low-acuity patients on multiple days, they could be enrolled as intervention or control patients multiple times. Patients' alarm rates were calculated by dividing the number of alarms by their length of stay to the minute. There was no adjustment made for patients enrolled more than once.

Human Subjects Protection

The Institutional Review Board of The Children's Hospital of Philadelphia approved this study with a waiver of informed consent.

Alarm Capture

We used BedMasterEx (Excel Medical Electronics; Jupiter, FL, <http://excel-medical.com/products/bedmaster-ex>) software connected to the General Electric monitor network to measure alarm rates. The software captured, in near real time, every alarm that occurred on every monitor in the PICU. Alarm rates over the preceding 4 hours for all PICU patients were exported and summarized by alarm type and level as set by hospital policy (crisis, warning, advisory, and system warning). Crisis and warning alarms were included as they represented potential life-threatening events meeting the definition of priority alarms. Physicians used an order within the PICU admission order-set to order monitoring based on preset age parameters (see online Appendix 1 for default settings). Physician orders were required for nurses to change alarm parameters. Daily electrode changes to reduce false alarms were standard of care.

Primary Outcome

The primary outcome was the change in priority alarm activation rate (the number of priority alarms per day) from prehuddle period (24 hours before morning huddle) to post-huddle period (the 24 hours following morning huddle) for intervention cases as compared with controls.

Primary Intervention

The intervention consisted of integrating a short script to facilitate the discussion of the alarm data during existing safety huddle and rounding workflows. The discussion and subsequent workflow proceeded as follows: A member of the research team who was not involved in patient care brought an alarm data sheet for each randomly selected intervention patient on the east wing to each safety huddle. The huddles were attended by the outgoing night charge nurse, the day charge nurse, and all bedside nurses working on the east wing that day. The alarm data sheet provided to the charge nurse displayed data on the 1 to 2 alarm parameters (respiratory rate, heart rate, or pulse oximetry) that generated the highest number of alarms. The charge nurse listed the high-alarm patients by room number during huddle, and the alarm data sheet was given to the bedside nurse responsible for the patient to facilitate further scripted discussion during bedside rounds with patient-specific information to reduce

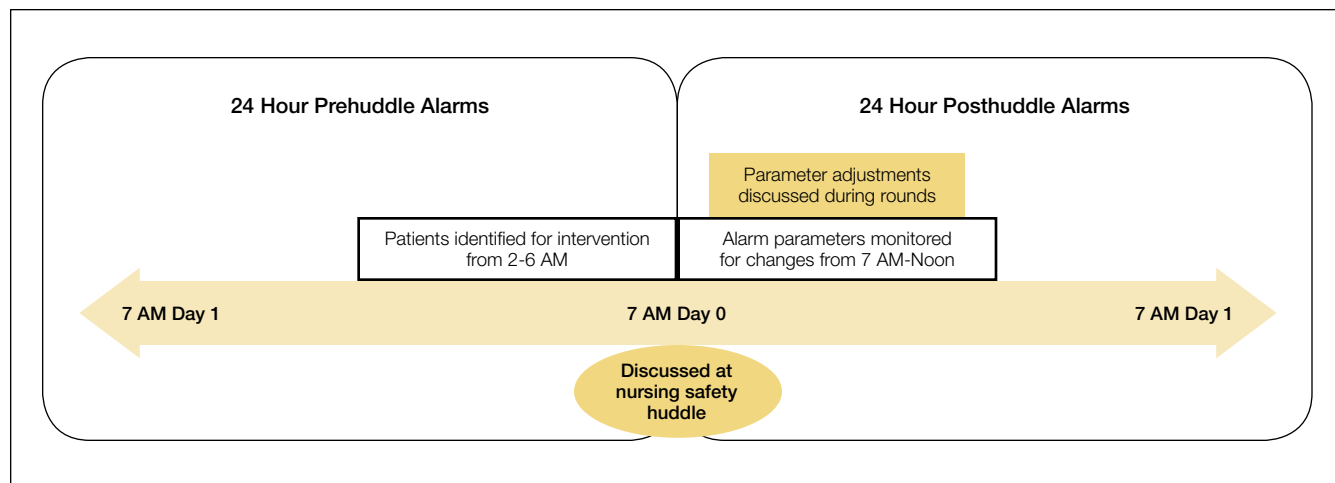


FIG 1. Schematic of study design for intervention patients.

the alarm rates of individual patients throughout the adjustment of physiologic monitor parameters (see Appendix 2 for sample data sheet and script).

Data Collection

Intervention patients were high-alarm, low-acuity patients on the east wing from June 1, 2015, through October 31, 2015. Two months of baseline data were gathered prior to intervention on all 3 wings; therefore, control patients were high-alarm, low-acuity patients throughout the PICU from April 1, 2015, to May 31, 2015, as historical controls and from June 1, 2015, to October 31, 2015, as concurrent controls. Alarm rates for the 24 hours prior to huddle and the 24 hours following huddle were collected and analyzed. See Figure 1 for schematic of study design.

We collected data on patient characteristics, including patient location, age, sex, and intervention date. Information regarding changes to monitor alarm parameters for both intervention and control patients during the posthuddle period (the period following morning huddle until noon on intervention day) was also collected. We monitored for code blue events and unexpected changes in acuity until discharge or transfer out of the PICU.

Data Analysis

We compared the priority alarm activation rates of individual patients in the 24 hours before and the 24 hours after the huddle intervention and contrasted the differences in rates between intervention and control patients, both concurrent and historical controls. We also divided the intervention and control groups into 2 additional groups each—those patients whose alarm parameters were changed, compared with those whose parameters did not change. We evaluated for possible contamination by comparing alarm rates of historical and concurrent controls, as well as evaluating alarm rates by location. We used mixed-effects regression models to evaluate the effect of the intervention and control type (historical or concurrent) on alarm rates, adjusted for patient age and sex.

Analysis was performed using Stata version 10.3 (StataCorp, LLC, College Station, TX) and SAS version 9.4 (SAS Institute Inc., Cary, NC).

RESULTS

Because patients could be enrolled more than once, we refer to the instances when they were included in the study as “events” (huddle discussions for intervention patients and huddle opportunities for controls) below. We identified 49 historical control events between April 1, 2015, and May 31, 2015. During the intervention period, we identified 88 intervention events and 163 concurrent control events between June 1, 2015, and October 31, 2015 (total $n = 300$; see Table 1 for event characteristics). A total of 6 patients were enrolled more than once as either intervention or control patients.

UNADJUSTED ANALYSIS OF CHANGES IN ALARM RATES

The average priority alarm activation rate for intervention patients was 433 alarms (95% confidence interval [CI], 392-472) per day in the 24 hours leading up to the intervention and 223 alarms (95% CI, 182-265) per day in the 24 hours following the intervention, a 48.5% unadjusted decrease (95% CI, 38.1%-58.9%). In contrast, priority alarm activation rates for concurrent control patients averaged 412 alarms (95% CI, 383-442) per day in the 24 hours leading up to the morning huddle and 323 alarms (95% CI, 270-375) per day in the 24 hours following huddle, a 21.6% unadjusted decrease (95% CI, 15.3%-27.9%). For historical controls, priority alarm activation rates averaged 369 alarms (95% CI, 339-399) per day in the 24 hours leading up to the morning huddle and 242 alarms (95% CI, 164-320) per day in the 24 hours following huddle, a 34.4% unadjusted decrease (95% CI, 13.5%-55.0%). When we compared historical versus concurrent controls in the unadjusted analysis, concurrent controls had 37 more alarms per day (95% CI, 59 fewer to 134 more; $P = 0.45$) than historical controls. There was no

TABLE 1. Characteristics of Intervention, Concurrent Control, and Historical Control Events (huddle discussions for intervention patients and huddle opportunities for controls, total n = 300)

Characteristics	Intervention (N = 88)	Concurrent Controls (N = 163)	Historical Controls (N = 49)	P Values
Age Group, % (N)				=.29
0-6 months	10% (9)	14% (23)	6% (3)	
6-12 months	7% (6)	8% (13)	6% (3)	
1-3 years	16% (14)	17% (28)	31% (15)	
3-6 years	14% (12)	19% (31)	14% (7)	
>6 years	53% (47)	42% (68)	43% (21)	
Male Sex, % (N)	63% (55)	48% (78)	45%(22)	=.050
Location, % (N)				<.001
PICU East Wing	100% (88)	28% (45)	69%(34)	
PICU West and South Wing	0% (0)	72% (118)	31%(15)	

NOTE: Six patients were included in more than 1 event. Abbreviation: PICU, pediatric intensive care unit.

TABLE 2. Adjusted Effect of the Intervention and Potential Confounders on the Change in Number of Alarms Per Day.

Control Types and Intervention	Estimated change in number of alarms per day	P Values	95% Confidence Interval
Intervention (vs Concurrent Controls)	116 fewer	.004	195 fewer to 37 fewer
Intervention (vs Historical Controls)	69 fewer	.20	176 fewer to 38 more
Historical Controls (vs Concurrent Controls)	47 fewer	.35	144 fewer to 51 more
Male (vs Female)	7 fewer	.84	79 fewer to 64 more
Age			
6-12 months (vs 0-6 months)	15 fewer	.86	176 fewer to 146 more
1-3 years (vs 0-6 months)	34 fewer	.60	163 fewer to 94 more
4-6 years (vs 0-6 months)	115 more	.09	16 fewer to 246 more
>6 years (vs 0-6 months)	72 more	.21	42 fewer to 185 more

significant difference between concurrent and historical controls, demonstrating no evidence of contamination.

Adjusted Analysis of Changes in Alarm Rates

The overall estimate of the effect of the intervention adjusted for age and sex compared with concurrent controls was a reduction of 116 priority alarms per day (95% CI, 37-194; $P = 0.004$, Table 2). The adjusted percent decrease was 29.0% (95% CI, 12.1%-46.0%). There were no unexpected changes in patient acuity or code blue events related to the intervention.

Fidelity Analysis

We tracked changes in alarm parameter settings for evidence of intervention fidelity to determine if the team carried out the recommendations made. We found that 42% of intervention patients and 24% of combined control patients had alarm parameters changed during the posthuddle period ($P = 0.002$).

For those intervention patients who had parameters changed during the posthuddle period (N = 37), the mean

effect was greater at a 54.9% decrease (95% CI, 38.8%-70.8%) in priority alarms as compared with control patients who had parameters adjusted during the posthuddle period (n = 50), having a mean decrease of only 12.2% (95% CI, -18.1%-42.3%). There was a 43.2% decrease (95% CI, 29.3%-57.0%) for intervention patients who were discussed but did not have parameters adjusted during the time window of observation (n = 51), as compared with combined control patients who did not have parameters adjusted (N = 162) who had a 28.1% decrease (95% CI, 16.8%-39.1%); see Figure 2.

DISCUSSION

This study is the first to demonstrate a successful and safe intervention to reduce the alarm rates of PICU patients. In addition, we observed a more significant reduction in priority alarm activation rates for intervention patients who had their alarm parameters changed during the monitored time period, leading us to hypothesize that providing patient-specific data regarding types of alarms was a key component of the intervention.

In control patients, we observed a reduction in alarm rates over time as well. There are 2 potential explanations for this. First, it is possible that as patients stabilize in the PICU, their vital signs become less extreme and generate fewer alarms even if the alarm parameters are not changed. The second is that parameters were changed within or outside of the time windows during which we evaluated for alarm parameter changes. Nevertheless, the decline over time observed in the intervention patients was greater than in both control groups. This change was even more noticeable in the intervention patients who had their alarm parameters changed during the posthuddle period as compared with controls who had their alarm parameters changed following the posthuddle period. This may have been due to the data provided during the huddle intervention, pointing the team to the cause of the high alarm rate.

Prior successful research regarding reduction of pediatric alarms has often shown decreased use of physiological monitors as 1 approach to reducing unnecessary alarms. The single prior pediatric alarm intervention study conducted on a pediatric ward involved instituting a cardiac monitor care process that included the ordering of age-based parameters, daily replacement of electrodes, individualized assessment of parameters, and a reliable method to discontinue monitoring.¹³ Because most patients in the PICU are critically ill, the reliance on monitor discontinuation as a main approach to decreasing alarms is not feasible in this setting. Instead, the use of targeted alarm parameter adjustments for low-acuity patients demonstrated a safe and feasible approach to decreasing alarms in PICU patients. The daily electrode change and age-based parameters were already in place at our institution.

There are a few limitations to this study. First, we focused only on low-acuity PICU patients. We believe that focusing on low-acuity patients allows for reduction in nonactionable alarms with limited potential for adverse events; however, this approach excludes many critically ill patients who might be at highest risk for harm from alarm fatigue if important alarms are ignored. Second, many of our patients were not present for the full 24 hours pre- and posthuddle due to their low acuity limiting our ability to follow alarm rates over time. Third, changes in alarm parameters were only monitored for a set period of 5 hours following the huddle to determine the effect of the recommended rounding script on changes to alarms. It is possible the changes to alarm parameters outside of the observed posthuddle period affected the alarm rates of both intervention and control patients. Lastly, the balancing metrics of unexpected changes in OptiLink status and code blue events are rare events, and therefore we may have been underpowered to find them. The effects of

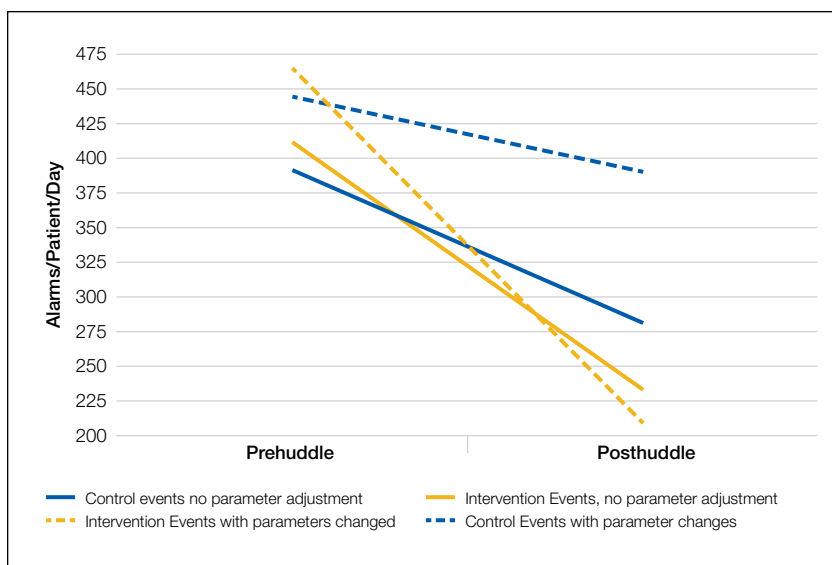


FIG 2. Overall changes in alarm rates per patient day for combined control events and intervention events stratified by alarm parameter change.

the huddle intervention on safety huddle length and rounding length were not measured.

CONCLUSION

Integrating a data-driven monitor alarm discussion into safety huddles was a safe and effective approach to reduce alarms in low-acuity, high-alarm PICU patients. Innovative approaches to make data-driven alarm decisions using informatics tools integrated into monitoring systems and electronic health records have the potential to facilitate cost-effective spread of this intervention.

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References

- Drew BJ, Califf RM, Funk M, et al. Practice standards for electrocardiographic monitoring in hospital settings: An American Heart Association scientific statement from the councils on cardiovascular nursing, clinical cardiology, and cardiovascular disease in the young. *Circulation*. 2004;110(17):2721-2746; DOI:10.1161/01.CIR.0000145144.56673.59.
- Paine CW, Goel V V, Ely E, et al. Systematic Review of Physiologic Monitor Alarm Characteristics and Pragmatic Interventions to Reduce Alarm Frequency. *J Hosp Med*. 2016;11(2):136-144; DOI:10.1002/jhm.2520.
- Schondelmeyer AC, Bonafide CP, Goel V V, et al. The frequency of physiologic monitor alarms in a children's hospital. *J Hosp Med*. 2016;11(11):796-798; DOI:10.1002/jhm.2612.
- Bonafide CP, Lin R, Zander M, et al. Association between exposure to nonactionable physiologic monitor alarms and response time in a children's hospital. *J Hosp Med*. 2015;10(6):345-351; DOI:10.1002/jhm.2331.
- Lawless ST. Crying wolf: false alarms in a pediatric intensive care unit. *Crit Care Med*. 1994;22(6):981-985; DOI:10.1016/0025-326X(92)90542-E.

6. Tsien CL, Fackler JC. Poor prognosis for existing monitors in the intensive care unit. *Crit Care Med*. 1997;25(4):614-619 DOI:10.1097/00003246-199704000-00010.
7. Talley LB, Hooper J, Jacobs B, et al. Cardiopulmonary monitors and clinically significant events in critically ill children. *Biomed Instrum Technol*. 2011;45(SPRING):38-45; DOI:10.2345/0899-8205-45.s1.38.
8. Rosman EC, Blafox AD, Menco A, Trope R, Seiden HS. What are we missing? Arrhythmia detection in the pediatric intensive care unit. *J Pediatr*. 2013;163(2):511-514; DOI:10.1016/j.jpeds.2013.01.053.
9. Korniewicz DM, Clark T, David Y. A national online survey on the effectiveness of clinical alarms. *Am J Crit Care*. 2008;17(1):36-41; DOI:17/1/36 [pii].
10. Voepel-Lewis T, Parker ML, Burke CN, et al. Pulse oximetry desaturation alarms on a general postoperative adult unit: A prospective observational study of nurse response time. *Int J Nurs Stud*. 2013;50(10):1351-1358; DOI:10.1016/j.ijnurstu.2013.02.006.
11. Joint Commission on Accreditation of Healthcare Organizations. Medical device alarm safety in hospitals. *Sentin Event Alert*. 2012:1-3.
12. Goldenhar LM, Brady PW, Sutcliffe KM, Muething SE, Anderson JM. Huddling for high reliability and situation awareness. *BMJ Qual Saf*. 2013;22:899-906; DOI:10.1136/bmjqs-2012-001467.
13. Dandoy CE, Davies SM, Flesch L, et al. A Team-Based Approach to Reducing Cardiac Monitor Alarms. *Pediatrics*. 2014;134(6):E1686-E1694. DOI: 10.1542/peds.2014-1162.