Stop the Noise: A Quality Improvement Project to Decrease Electrocardiographic Nuisance Alarms

Sue Sendelbach, RN, PhD, CCNS
Sharon Wahl, RN, MS, CCRN, CCNS
Anita Anthony, RN, MS, ACNS-BC, CCRN, PCCN-CMC
Pam Shotts, RN, BSN, CHC, CPC

Background As many as 99% of alarm signals may not need any intervention and can result in patients' deaths. Alarm management is now a Joint Commission National Patient Safety Goal.
Objectives To reduce the number of nuisance electrocardiographic alarm signals in adult patients on the medical cardiovascular care unit.
Methods A quality improvement process was used that included eliminating duplicative alarms, customizing alarms, changing electrocardiography electrodes daily, standardizing skin preparation, and using disposable electrocardiography leads.
Results In the cardiovascular care unit, the mean number of electrocardiographic alarm signals per day decreased from 28.5 (baseline) to 3.29, an 88.5% reduction.
Conclusion Use of a bundled approach to managing alarm signals decreased the mean number of alarm signals in a cardiovascular care unit. (*Critical Care Nurse*. 2015;35[4]:15-23)

From June 2009 through June 2012, The Joint Commission received 98 alarm-related event reports.[1] Of those, 80 resulted in deaths of patients, 13 resulted in permanent loss of function, and 5 resulted in additional care or an extended hospital stay. In spite of the Safe Medical Devices Act of 1990, which requires hospitals to report deaths and injuries related to medical devices, it is believed that the number of events is grossly underestimated.[2] In a recent survey examining attitudes and practices related to clinical alarms, 18% of respondents knew of an adverse event related to clinical alarm problems within the past 2 years that had occurred at their institution.[3]

CE Continuing Education

This article has been designated for CE credit. A closed-book, multiple-choice examination follows this article, which tests your knowledge of the following objectives:

1. List interventions used to decrease the number of electrocardiographic alarm signals in the cardiovascular care unit
2. Identify the 2 phases of The Joint Commission's National Patient Safety Goal
3. Discuss interventions identified in the literature that have been shown to reduce nuisance electrocardiographic alarm signals

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In addition to cases reported to The Joint Commission, the lay press has also highlighted deaths related to alarms, most recently, the death of a 17-year-old high-school junior who had come in for a routine tonsillectomy.[4] In addition to failed assessments, the monitoring equipment was not set properly and was muted, and when the patient's condition deteriorated, staff was not alerted by the equipment. Tragically, the patient sustained brain damage and died 15 days later.[4] These events, along with several other publicized cases, have highlighted the need to address the complex issue of alarm hazard aggressively.

Background Knowledge

Alarm fatigue occurs when alarm signals are so frequent that clinicians are overwhelmed to the point that patients' safety could be compromised if the alarms are disabled, silenced, or ignored.[5,6] The problem of alarm fatigue has become so consequential that the ECRI Institute has identified alarm fatigue as the No. 1 technology hazard for 4 years in a row.[7-10] The interest in this topic is further demonstrated by a recent webinar produced by the Advancement of Medical Instrumentation (AAMI) Foundation Healthcare Technology Safety Institute (HTSI) on alarm fatigue, for which registration reached the maximum capacity at 3500 persons, more than for any other previous conference, and included participants from all 50 states (personal communication, S. Fanta Lombardi, AAMI HTSI, March 5, 2014).

Alarm fatigue occurs when alarm signals are so frequent that clinicians are overwhelmed to the point that patients' safety could be compromised.

Recognizing the complexity and the increased frequency of patient events related to alarm hazards, The Joint Commission issued a sentinel event alert that urged hospitals to examine the effects of alarms on patient safety,[11] and that alert evolved into a National Patient Safety Goal (NPSG).[12] Previous to this, there had been an NPSG on clinical alarms that was designed to "improve the effectiveness of clinical alarms systems."[13(p434)] That goal had been retired in 2005[13] but was still able to be surveyed under Environment of Care EC.02.04.01, EC.02.04.03 (CoP Physical Environment 482.41), and under Provision of Care, Leadership and Patient Rights (CoPs: Nursing 482.23 and Patient Rights 482.13 [AAMI HTSI webinar, 2013][14]).

The first phase of the new NPSG requires hospitals to establish alarms as an organization priority and identify the most important alarms to manage depending on their own internal situations.[12] Phase II is to be implemented by January 2016, when hospitals will be expected to have developed and implemented specific components of policies and procedures related to alarm management. In addition, phase II includes educating staff and licensed independent practitioners about the purpose and proper operation of alarm systems.

Most research has been focused on identifying the number and types of alarms. In spite of the dire consequences of alarm fatigue for patients, little research has addressed interventions to increase alarm safety. However, limited quality improvement projects specific to electrocardiographic (ECG) monitoring have provided guidance on how to decrease nuisance and/or insignificant ECG alarms.[6,15-18] Suggested interventions have included daily ECG electrode changes, use of a standardized approach to ECG electrode changes, individualization of alarms to patients' needs, and elimination of redundant alarms.

Study Question

The purpose of this quality improvement project was to reduce the number of unnecessary ECG and pulse oximetry (Spo_2) alarms in a 16-bed adult medical cardiovascular care unit (CCU). The study question is, Can a

Authors

Sue Sendelbach is director of nursing research at Abbott Northwestern Hospital, Minneapolis, Minnesota, and is on the Association of the Advancement of Medical Instrumentation's committee on alarm management/alarm fatigue.

Sharon Wahl is a cardiovascular clinical nurse specialist at Abbott Northwestern Hospital and has facilitated several projects on alarm management within the critical care patient care units.

Anita Anthony is a clinical nurse specialist and at the time of the project worked in the progressive care unit at Abbott Northwestern Hospital. She is now at University of Minnesota Medical Center in Minneapolis.

Pamela Shotts is a quality specialist and manages the data for the alarm management project at Abbott Northwestern Hospital.

Corresponding author: Dr Sue Sendelbach, Abbott Northwestern Hospital, 800 East 28th Street, Minneapolis, MN 55407 (e-mail: sue.sendelbach@allina.com).

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Table Alarm settings in medical cardiovascular care unit (hardwire and telemetry)

Alarm	Default	Change	Grade (priority)	Record/store	Notes
Asystole	On		Life-threatening	Record/Store	Cannot be turned to off
Electrocardiography leads invalid (assessment lead disconnected)	On		Advisory but now sent to mobile device communication system	Record/store	Sent to mobile device communication system similar to life-threatening
Heart rate (high)	140/min	160/min	Serious	Store	Changed from record to store
Heart rate (low)	45/min	30/min	Serious	Store	Changed from record to store
Sinus bradycardia	40/min	45/min	Life-threatening	Record/store	
Sinus tachycardia	Off-default	None	Serious	Stores at >130/min	
Supraventricular tachycardia	150/min	140/min	Serious	Store	
Ventricular fibrillation	On		Life-threatening	Record/store	Cannot be turned to off
Ventricular tachycardia	130/min	140/min	Life-threatening	Record/store	
Couplet	On	Off		Store	
Bigeminy	On	Off		Store	
Oxygen saturation shown by pulse oximetry	89%	88%	Serious		

bundled approach of interventions decrease the number of nuisance ECG alarm signals?

Methods

Ethical Issues

This project was submitted to the institutional review board, which determined that it did not meet the criteria for human subject research.

Setting

The quality improvement project was conducted in a 16-bed, Beacon-certified, adult medical coronary care unit within a tertiary care, Magnet hospital that is staffed for 627 beds. The primary populations of patients are patients with acute coronary syndrome or advanced heart failure and patients undergoing induced hypothermia after cardiac arrest. The physical unit design is a central desk with rooms on either side in a Y shape. The charge nurse frequently silences alarms at the central desk and alerts staff if action is needed, as nurses may be caring for patients at opposite ends of the unit.

Process

In order to determine how to address ECG alarms, an interprofessional team met to discuss and understand our ECG monitoring system. The first step in the process was to collect data to determine the baseline number of alarms being sent to the clinical staff. Capturing the data on the number and types of alarms was challenging, and that process was managed by a senior analyst from the information systems department. Data were collected weekly (7 AM Monday morning to 7 AM the following Monday) and compiled into an MS Excel (Microsoft Inc) spreadsheet.

Alarms signals are those triggered by issues related to either patient or systems. Alarm signals related to patients are those alarms that are specific to a patient's clinical status, such as arrhythmia or low heart rate. Alarm signals related to systems are triggered by either mechanical or electrical problems.[6] The priority of the alarms is divided up according to the seriousness of the problem that is causing the alarm and is dependent on how the manufacturer has categorized the alarm. Alarm priority ranges from a critical level that requires immediate attention to a low level of concern (see Table). Alarms triggered by life-threatening events have the highest priority; these alarms must be acknowledged and silenced at the bedside or central monitor. Serious audible alarms sound, but the noise terminates when the trigger abates. An icon remains on the monitor to notify staff until the alarm has been reviewed and the icon eliminated. Advisory alarms ring and terminate with resolution of the trigger; these alarms are the lowest priority. The 4 alarm signals for life-threatening events within our system include alarms for (1) asystole, (2) bradycardia, (3) ventricular fibrillation, and (4) ventricular tachycardia. Alarms for life-threatening events are a small percentage of total alarms, and nurses respond to these promptly. Serious alarms comprise a larger percentage of overall alarms and are often considered nuisance alarms—the trigger for the alarm does not require immediate response and, in fact, may be false.

Next a quality improvement process, a rapid process improvement workshop, was initiated.[19] Similar to other quality improvement methods, rapid changes in practice are planned, implemented, evaluated, and continued or changed depending on the outcomes. Potential interventions that were identified included (1) deletion of duplicative alarms, (2) customization of alarms on the basis of the patient's need, (3) daily changes of ECG electrodes, (4) standardized skin preparation, and (5) use of disposable ECG monitoring leads. In the CCU, Spo_2 measurement alarms were identified as an additional area for improvement as they accounted for the most false alarms. Further interventions were aimed at decreasing the number of these alarms as well. This quality improvement project began in March 2013 and ended in August 2013.

A multipronged approach to managing ECG alarm signals decreased the mean number of ECG alarm signals in a cardiovascular care unit.

Potential Interventions

Eliminating Duplicative Alarms Unexpectedly, the monitoring systems had separate alarms for both "tachycardia" and "high heart rate" and, conversely, for both "bradycardia" and "low heart rate." For example, if the tachycardia and high heart rate alarms were both set to go off at 150 beats per minute, both alarms would be triggered and the nurse would need to silence 2 different alarms. Different levels of alarm significance had been assigned to each alarm, which resulted in multiple alarms.[18]

Adjusting Default Alarms The units' default alarm settings were carefully evaluated and opportunities to eliminate duplicate alarms and safely reduce other alarms were identified so that alarms that did occur would be actionable and clinically significant. Proposed changes to default alarm settings were approved by an interprofessional governing body and by the medical director to ensure that any issues that might reduce patient safety could be identified in advance. A decision was made to change the alarm settings to provide consistency with the designation: alarms for life-threatening events received the highest priority and an ECG strip would print when triggered. Alarms for events that were not life threatening were changed from record to store. All alarms were stored and viewable.

The most common alarms were for bigeminy and for couplets, accounting for as many as 87% of all alarm signals weekly. These alarms had little relevance because isolated bigeminal and couplet beats are not treated in our current practice, consistent with the results of the 1988 CAST trial, which demonstrated a higher rate of death in patients treated with encainide and flecainide versus placebo.[21,22] These alarms could also be incorporated into other alarms that could be customized for each patient. After consultation with physicians, we changed the default setting for the bigeminy and couplet alarms to off, with nurses having the option to turn these alarms on if the patient's condition warranted doing so.

Customizing Alarms Nurses were instructed to ensure that alarms were tailored to the patients' condition. Appropriate complex size was adjusted to enable the monitor to provide appropriate rhythm analysis. Asystole alarms often were triggered by incorrect readings of paced rhythms, often because of the lack of the "pace detect" function. Activation of this function assists in analyzing and determining paced rhythms, so the system was set with the pace-detect function as a default. The default allowed nurses to focus on other issues related to monitoring patients. Often alarms occurred when the patient was disconnected from the monitor, such as during tests or when the patient was in the shower. Strong encouragement was made to place patients' monitors on "standby" status, thus decreasing the number of avoidable alarms.

Daily Changes of ECG Electrodes The hospital's policy for changing ECG monitoring electrodes stated that "patches [electrodes] will be changed every 2 days" consistent with the skills for cardiac monitor setup and lead placement specified in the American Association for Critical-Care Nurses' (AACN's) *AACN Procedure Manual for Critical Care.*[23] For this pilot study, we initiated daily electrode changes.[16]

Standardized Skin Preparation for ECG Electrodes Skin preparation was based on the AACN's practice alert for alarm management[24] and included (1) washing the isolated electrode area with soap and water, (2) wiping the electrode area with a rough washcloth or gauze and/or using the sandpaper on the electrode to roughen a small area of the skin, and (3) eliminating alcohol for skin preparation to prevent the skin from drying out.

Use of Disposable ECG Lead Wires Anecdotally, disposable electrode wires have been associated with a decrease in alarm signals, thus providing a better quality signal and more secure fit to the ECG electrodes, resulting in fewer system alarms related to problems with electrodes or leads (eg, "leads invalid" alarms). In this quality improvement project, a 2-week trial of disposable ECG leads was pilot tested in the CCU.

Spo_2 Monitors Graham and Cvach[6] demonstrated that one of the largest contributors to the number of nuisance alarms was the pulse oximetry alarm. This alarm is relatively quiet at the bedside but is markedly amplified at the central desk, a function of the monitoring system that cannot be changed. Minimal interventions were identified that could reduce nuisance Spo_2 alarms. Welch[25] demonstrated that by decreasing the threshold on the Spo_2 from 90% to 88%, alarms could be decreased by 45%.

Given the limitations of our monitors, alternative strategies were employed to reduce the number of Spo_2 alarms. The threshold (ie, at what oxygen saturation the alarm would go off) was decreased from 90% to 88%. All patients in the CCU are started on Spo_2 monitoring at admission, and nurses were encouraged to evaluate the appropriateness of continued monitoring after 24 hours and to consult with physicians to discontinue Spo_2 monitoring on patients who were stable on room air, a practice supported by hospital policy. Education was provided to staff on proper selection and placement of sensors. Forehead probes were encouraged for patients who were mobile in an effort to reduce artifact alarms associated with activity.

Analysis

Descriptive statistics were used to identify the changes over time. Patient-related alarm conditions were identified on the basis of physiological conditions: (1) asystole, (2) sinus bradycardia, (3) supraventricular tachycardia, (4) ventricular fibrillation, (5) ventricular tachycardia, (6) arrhythmia: bigeminy, and/or (7) arrhythmia: couplet. System issues leading to alarms were either (1) ECG leads invalid or (2) ECG artifact. Totals were calculated for the physiological alarm conditions and the system alarm conditions each week (7 AM Monday to 7 AM Monday). 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 addition, the rate of the alarms for life-threatening events and the rate for the system alarms per day were also divided by the mean daily census to determine the rate of alarm signals by priority.

Results

In this quality improvement project, 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 was associated with an 80% to 90% reduction in ECG alarms in the CCU (see Figure). The baseline data (April 4-11, 2013) revealed a mean of 28.5 total alarm signals per day per monitored bed, of which a mean of 3.58 were system alarms and alarms for life-threatening events. After implementation of interventions (August 12-August 19, 2013), 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). This change has been sustained, as evidenced by an assessment of the number of ECG alarm signals in December 2013 that demonstrated a mean of 3.05 alarm signals per day per patient.

> A 2-week trial of use of disposable leads in the cardiovascular care unit failed to show any significant change in alarm rates.

A 2-week trial of use of disposable leads in the CCU failed to show any significant change in alarm rates. Anecdotally, nurses reported that leads did fit more securely, but the use of disposable leads did not correlate with a decrease in alarms.

Despite our changing the threshold for Spo_2 alarm signals from 90% down to 88%, no changes in alarm rates were noted. No adverse patient events were associated with the lower threshold, but the change had little effect on the overall number of Spo_2 alarms generated. Nurses

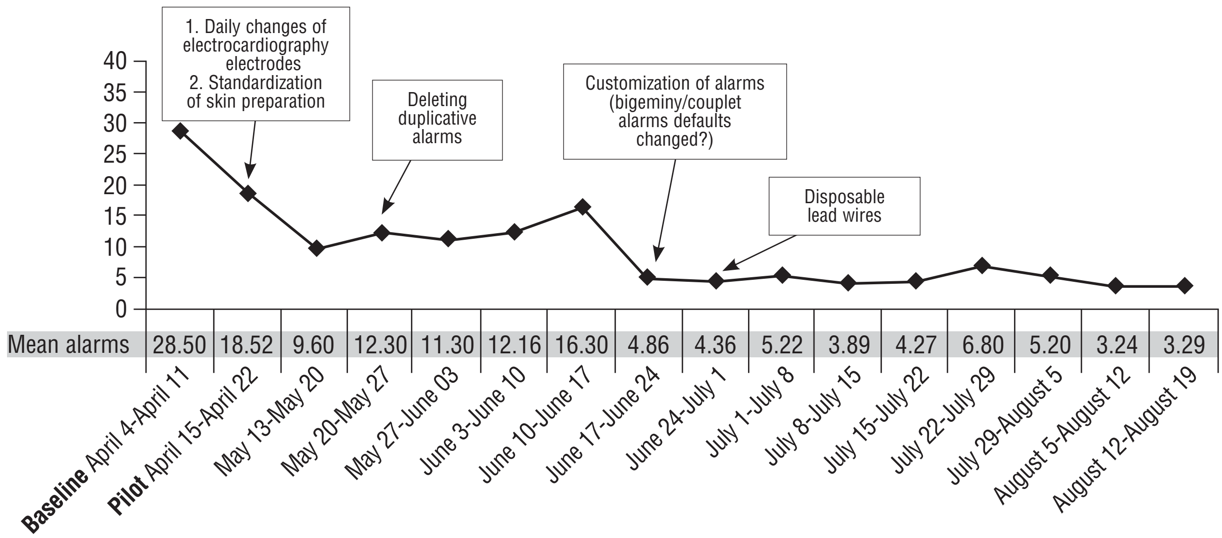

Figure Mean number of alarm signals/day per monitored bed in the medical cardiovascular unit (April 4-August 19).

are encouraged to customize this alarm as indicated, but our current technology has a set delay of 4 seconds and does not support signal averaging.

Discussion

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 (see Figure). This reduction is consistent with other published quality improvement efforts.[6,16,18] However, unlike Graham and Cvach,[6] we were unable to change the number of oxygen saturation alarms even after decreasing the threshold from 90% to 88%.

Although the intent of ECG alarm systems is to enhance patient safety, published reports indicate that between 72% and 99%[26-32] of alarms are false or nonactionable, which actually creates a safety risk. Because of the number of nuisance alarm signals, care providers can experience a "cry wolf" effect, leading to desensitization and alarm system mistrust, so that real events are less likely to be acted on.[33-35] Eventually, this situation has led staff to begin to mistrust the alarm system so that real events are less likely to be acted on.[33-36] Breznitz[36] has termed this the "false-alarm effect" and has posited that the more sensitive a warning system is, the greater is the effect from repeated false alarms because weaker signals will be detected, thus creating more alarm signals. This issue of sensitivity may have been part of the reason for the results in a recently published study,[37] which demonstrated that, of 17 "crisis level" alarms that occurred, 16 were ventricular tachycardia alarms, 9 were for artifacts, and none of the alarm signals was for a true ventricular tachycardia. In addition, the 17th alarm signal was for asystole and also was false. These results are particularly distressing because it has been demonstrated that if a person experiences a system to be 10% reliable, then the person will respond 10% of the time.[34,38,39] The dire consequences of the number of nuisance alarms has been demonstrated when the alarm limits are extended, disabled, or not returned to their original settings, resulting in patients dying.[4,40,41]

The most significant change was in number of the bigeminy and/or couplets alarm signals, which accounted for the vast majority of the alarm signals (ie, 25 of the 28.5 alarm signals per day per monitored bed). 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. This reduction was accomplished without compromising patient safety in that the bigeminy and/or couplets were captured in the number of premature ventricular contractions per minute or the number of premature ventricular contractions in a row.

We were unable to demonstrate a change in Spo_2 alarms. This result was disappointing because nurses find the Spo_2 alarm one of the more irritating alarms. Once we were able to decrease the number of nuisance alarms from the ECG monitor, the Spo_2 alarm became even more irritating because it was more prominent. We were limited by the fact that our only option was to decrease the alarm threshold because the technology did not support a slight delay to allow for alarm correction (ie, we were unable to change the number of seconds before an alarm is triggered).

Disposable ECG lead wires were not associated with a change in alarms. However, when we started using disposable ECG wires, the rate of alarm signals was so low that no matter what intervention was implemented, the results might have been the same. We suspect that this was not a fair assessment of the use of disposable ECG lead wires.

This quality improvement project using a rapid process improvement workshop provided an approach for implementation of the same interventions on other patient care units within the hospital. The identified interventions were replicated in the cardiovascular surgical intensive care unit, where they yielded equally successful outcomes. This approach will continue to be used as the interventions are implemented throughout the hospital.

Limitations

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. As waveforms were not validated, we do not know if the remaining alarm signals were true or clinically significant. However, the number of alarm signals for life-threatening events did not decrease with the pilot study, indicating that we continue to capture the meaningful alarms.

Conclusions

This quality improvement project demonstrated that implementation of a bundle of interventions can reduce the frequency of nuisance alarm signals in patients in a CCU and that the reduction can be sustained over time. However, we were not able to change the number of nuisance Spo_2 alarms, most likely because of the limitations of our technology. CCN

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Financial Disclosures
None reported.

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To learn more about decreasing nuisance alarms, read "Monitor Alarm Fatigue: Standardizing Use of Physiological Monitors and Decreasing Nuisance Alarms" by Creighton Graham and Cvach in the *American Journal of Critical Care*, January 2010;19:28-34. Available at **www.ajcconline.org.**

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