A Team-Based Approach to Reducing Cardiac Monitor Alarms

abstract

BACKGROUND AND OBJECTIVES: Excessive cardiac monitor alarms lead to desensitization and alarm fatigue. We created and implemented a standardized cardiac monitor care process (CMCP) on a 24-bed pediatric bone marrow transplant unit. The aim of this project was to decrease monitor alarms through the use of team-based standardized care and processes.

METHODS: Using small tests of change, we developed and implemented a standardized CMCP that included: (1) a process for initial ordering of monitor parameters based on age-appropriate standards; (2) pain-free daily replacement of electrodes; (3) daily individualized assessment of cardiac monitor parameters; and (4) a reliable method for appropriate discontinuation of monitor. The Model for Improvement was used to design, test, and implement changes. The changes that were implemented after testing and adaptation were: family/patient engagement in the CMCP; creation of a monitor care log to address parameters, lead changes, and discontinuation; development of a pain-free process for electrode removal; and customized monitor delay and customized threshold parameters.

RESULTS: From January to November 2013, percent compliance with each of the 4 components of the CMCP increased. Overall compliance with the CMCP increased from a median of 38% to 95%. During this time, the median number of alarms per patient-day decreased from 180 to 40.

CONCLUSIONS: Implementation of the standardized CMCP resulted in a significant decrease in cardiac monitor alarms per patient day. We recommend a team-based approach to monitor care, including individualized assessment of monitor parameters, daily lead change, and proper discontinuation of the monitors. *Pediatrics* 2014;134:e1686–e1694
Physiologic monitoring systems generate visual and audible alarm signals to alert staff to changes in the patient’s clinical status. However, each patient can generate hundreds of alarms per day, resulting in thousands of alarms overall for the unit. In fact, some high-acuity units experience up to 350 physiologic monitor alarms per patient per day. Providers feel overwhelmed as they differentiate between the large amount of alarms, and they may become desensitized. Desensitization to alarms, or “alarm fatigue,” leads to a lack of response to the alarms due to sensory overload.

In January 2010, excessive alarms reached national headlines when a patient’s death was directly related to alarm fatigue. However, the dangers from excessive alarms are more than an isolated case. From 2005 to 2010, the Emergency Care Research Institute reported 216 physiologic monitor-related deaths. The institute publishes an annual top 10 technology list, and “Alarm Hazards” has been at the top of the list for the last several years.

In April 2013, the Joint Commission announced a Sentinel Event Alert to all hospitals based on alarm fatigue and cardiac monitor device care. They reported 80 alarm-related deaths between January 2009 and June 2012, all traced back to alarm-related issues. The major factors reported in these deaths were from alarm fatigue, alarm parameters not customized to the patient, and inadequate staff training on the functioning of the monitors.

The present improvement project was performed in the bone marrow transplant (BMT) unit at Cincinnati Children’s Hospital Medical Center (CCHMC). Hospital guidelines recommend cardiopulmonary monitoring when patients receive patient-controlled analgesia, infusions, transfusions, and/or when clinically indicated. During a 3-month period before implementation of our improvement process, the BMT unit had 478,143 cardiac monitor alarms. This total averaged to 5,300 alarms per day or 250 alarms per monitor per day. Family and staff commonly complained of the frequency of alarms, and personal communication with the nursing staff revealed that they spent on average 20 to 25 minutes per shift attending to the alarms of patients requiring monitoring. In addition, ~95% of the alarms on the floor were false alarms. Despite the high frequency of alarms, there were no acute patient decompensations missed because of alarm fatigue, but the high frequency of alarms raised important safety concerns.

The aim of the present project was to create and implement a standardized process for cardiac monitor care to decrease the number of nuisance alarms on the BMT floor. We hypothesized that this process would result in a decrease in the total number of nuisance alarms without missing true patient decompensation.

METHODS

In January 2012, we established a multidisciplinary alarm oversight task force consisting of key stakeholders, including physicians, nurse practitioners (NPs), nursing leadership, registered nurses (RNs), patient care assistants (PCAs), clinical engineering, and patient family representatives. The team reviewed the current cardiac monitor care practice, published recommendations, identified gaps between practice and evidence, and identified areas of improvement. Using the Model of Improvement, we identified a reliable mechanism to implement the specific processes and tested hypotheses by using Plan-Do-Study-Act (PDSA) measures.

Our focus was to create a standardized, team-centered, cardiac monitor care process (CMCP) that could be implemented throughout the BMT unit for patients undergoing cardiopulmonary monitoring. The CMCP included: (1) age-appropriate parameters for patients upon placement on a cardiac monitor; (2) daily electrode changes; (3) daily evaluation of cardiopulmonary monitor parameters; and (4) timely discontinuation of the monitor once the patient was off patient-controlled analgesia or clinically stable.

Context

CCHMC is a large, urban pediatric medical center, and the BMT team performs 100 to 110 transplants per year. The BMT unit contains 24 beds, and 60% to 70% of patients on the floor are on cardiac monitors, which include pulse oxygen saturation (SpO2) monitoring as well as cardiopulmonary monitoring. Patients admitted to the BMT unit are often hospitalized for up to 30 to 40 days, and they can be on monitors for 50% to 60% of their hospitalization. The clinical providers caring for the patients include 14 BMT attending physicians, 15 fellows, 7 NPs, and 6 hospitalists. Residents do not rotate on the BMT unit. NPs and hospitalists place the majority of the orders on the BMT unit, and hospitalists provide 24-hour coverage for all patients on the floor. The BMT unit employs ~130 bedside RNs and 30 PCAs. Family members take an active role in the care of patients in the BMT unit as participants in the Family Advisory Council and through daily family-centered rounds.

Improvement

Before any intervention, we analyzed our monitor care delivery over a 2-week period of time. This investigation revealed several deficits in cardiac monitor care: (1) only 20% of the monitors were programmed to age-appropriate parameters upon initiation of cardiopulmonary monitoring; (2) the electronic medical record did not contain monitor parameter orders to allow communication between the physician team and the nursing staff; (3) there was no standard process for electrode replacement; (4) random
sampling revealed that electrodes were placed in the wrong location 30% of the time; (5) electrodes were replaced infrequently (up to every 2 weeks); and (6) the monitors were not set according to the patient’s specific needs (ie, a patient with persistent fever would have a high heart rate parameter of 120 beats per minute despite persistent tachycardia [130 beats per minute]).

The CMCP was based primarily on our observations of monitor care delivery and PDSA testing. A cardiac monitor log was created to track compliance. Monitor parameters, subjective issues with the alarms, electrode change during the previous 24 hours, and anticipated discontinuation of the monitor were documented daily in the monitor log by the nursing staff and discussed with the hospitalist service each afternoon. Monitor parameters were scrutinized against current vital signs and appropriate clinical need.

Family Engagement

Family members helped identify barriers to implementation of the CMCP as participants of the multidisciplinary team. The lead change protocol was discussed with family members on initiation of the cardiac monitoring. Family members and patients communicated problems with alarms to the nursing staff, and these issues were addressed directly and documented in the monitor log. Family perception of timely attendance to monitors by staff was measured in the BMT patient satisfaction questionnaire.

Standardized Reliable Process for Age-Appropriate Ordering of Monitor Parameters

An age-appropriate order set with baseline parameters was created in the electronic medical record. With the use of this order set, the staff was able to change the monitor orders if needed. Initial monitor parameters were documented on the cardiac monitor log, and accuracy was verified on the day of admission by the NP and the hospitalist team.

Daily Lead Change

Daily electrode change was based on manufacturer guidelines, published findings, and PDSA testing results. Prolonged electrode duration can result in signal impedance and increased signal noise due to decreased conductivity, which lead to increased false alarms. Cvach et al demonstrated a 46% decrease in the number of alarms per day with daily electrode replacement. Our PDSA testing showed similar findings, with a 25% to 30% increase in alarms for each additional day the patient’s leads were not changed. Finally, we estimated the hospital cost for lead replacement to be <$1.00 per day.

Daily Assessment of Monitor Parameters

The cardiac monitor log was completed daily by the nursing staff and reviewed daily by the medical team. Excessive false alarms were investigated and corrected by the nursing staff with the use of monitor troubleshooting algorithm.

Clearly Defined Roles and Responsibilities

All staff received education through a mandatory computer module and with direct interaction with the various CMCP team members. PCAs were responsible for daily lead changes; RNs documented and verified lead changes, monitored settings, and anticipated discontinuation of the monitor on the monitor care log, and the charge nurses reviewed the log with the providers daily. Intermittently, throughout the study, we asked nurses how much time they spent addressing alarms and performing alarm care. These data were used to test the effectiveness of the interventions.

Standardized Reliable Process for Monitor Discontinuation

We created intentional redundancy in the assessment of the discontinuation of the monitors. Both providers and nurses assessed the need for the cardiac monitors, and this information was documented in the cardiac monitor log. For patients on a monitor secondary to patient-controlled analgesia use, the pain team created a reliable system to verify discontinuation of the monitor once it was no longer needed.

Customized Monitor Delay and Increased Threshold Settings

Customized monitor delays and increased parameter threshold settings have been shown to be an effective method for reducing false alarms. We increased the Spo2 alarm delay from 5 to 10 seconds because the majority of the Spo2 alarms self-correct within the delay period set. High respiratory rate, without other vital sign abnormalities, is nearly always a false alarm. The safety of increasing the respiratory rate on monitors was evaluated by the hospital oversight committee, and in our unit, the high respiratory rate was determined to not be an actionable alarm alone; therefore, the high respiratory rate limit on all monitors on the floor was increased.

Study of the Improvement

The process was analyzed through a quantitative time series study design. We measured each component of the CMCP individually and cumulatively. The measured CMCP components included: (1) standardized process of initial ordering and setting of monitor parameters based on age-appropriate standards; (2) pain-free daily replacement of electrodes; (3) daily individualized assessment of cardiac monitor parameters; and (4) appropriate discontinuation of the monitor when it was no longer indicated (Fig 1). On a weekly basis, each component of the process was measured independently as a percentage of patients who had the intervention (numerator) over the number of opportunities.
We measured the CMCP in whole as a percentile of the number of completed components of the CMCP over the number of opportunities. For example, if a patient was admitted on day 1 and the correct parameters were applied to the monitor, electrodes were replaced daily for 5 days, the patient received daily evaluation of proper parameters for 5 days, and the monitor was discontinued appropriately, then this method would equate to 12 opportunities.

We measured the number of alarms per monitored day on monitored patients. This amount was calculated as a total sum of the number of alarms, divided by the number of monitor days on the unit during the preceding week. Finally, as a balancing measure, we examined each code blue and staff emergency to determine if a change in the cardiac monitor care could have recognized the clinical status change at an earlier time.

**Data Collection**

Data to generate the measures and weekly reports were collected daily on the monitor log, which was a communication tool between the nursing staff and the physician team. The log included current monitor parameters, family and nursing concerns regarding monitors, electrode change, and anticipated discontinuation of the cardiac monitor. The data from these sheets were collected and assessed weekly.

**Analysis**

The difference in family perception of timely response before and after the intervention was evaluated by using Fisher’s exact test. Statistical process control methods were used to monitor changes in care processes and health outcomes. Annotated run charts and U charts were developed and updated weekly. We established a median, illustrated as the centerline on all control charts with upper and lower control limits in the U charts. Standard industry criteria were used to determine if observed changes in measures were chance random variation (common cause variation) or due to a specific assignable cause, in this case the intervention (special cause variation).14,15

**Human Subjects Protection**

The present initiative fell within the CCHMC institutional review board’s guidance for quality improvement projects that did not constitute human subjects research.

![Key Driver Diagram of the CMCP Implementation](http://pediatrics.aappublications.org/)

**FIGURE 1**

Key driver diagram of the CMCP implementation. CMCL, cardiac monitor care log; EMR, electronic medical record.
RESULTS

The study period was from January 2013 through November 2013 (Fig 2). Initial PDSA testing on electrode replacement, the timing of electrode replacement, and the timing of daily assessment of monitor parameters occurred in January and February. In March, formal education was given to all nursing staff in the form of an online module. In June, we increased the high respiratory rate on all monitors, and in July we increased the SpO2 alarm delay.

Compliance With the CMCP

Overall compliance with the CMCP remained stable at a median of 38% (range: 33%–43%) through February 2013 as PDSA testing was accomplished. Once roles and responsibilities were determined and the process was clearly defined, full implementation continued on the unit. This process occurred primarily in March 2013. The unit’s overall compliance with the CMCP increased to a median of 95% (range: 73%–98%), which was sustained for 7 months from May to November 2013 (Fig 3).

With redundancy in the system, we maintained a high degree of reliability in patients having proper initial monitor parameters (Fig 4A). This reliability was accomplished with the creation of the age-specific monitor parameter settings in the electronic medical record order set, as well as daily review by the providing team. With the use of PDSA testing, we discovered improved sustainability of daily evaluation of the

![Compliance With the CMCP Graph](http://pediatrics.aappublications.org/)

FIGURE 3
Overall compliance with the CMCP. Measured as percent compliance (number of completed interventions/number of opportunities).
parameters (Fig 4B) by having the cardiac monitor log completed by the nursing staff during the day and with review by the hospitalist service in the afternoon.

Patient discomfort was the largest barrier to daily lead change. PDSA testing revealed that soaking the leads with water while taking a bath, for at least 1 minute, reduced patient pain. Daily lead change compliance improved from a median of 55% (range: 41%–69%) to 85% (range: 63%–97%) during the 11-month period (Fig 4C).

Multiple interventions enabled a high percentage of patients being taken off monitors appropriately (Fig 4D). Nursing staff documented and discussed the anticipated monitor discontinuation date daily.

**Number of Alarms**

As CMCP compliance improved, there was a decrease in the number of alarms,

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**FIGURE 4**

Compliance with the individual components of the CMCP. A, Percent compliance with age-appropriate alarm parameters upon placement on the monitor. B, Percentage of patients with daily assessment of alarm parameters. C, Percentage of leads replaced daily. D, Percentage of monitors discontinued appropriately.
from a median of 180 to 40 during the study period (Fig 5). We maintained a rate of 50 to 70 alarms per day with utilization of the CMCP alone and were able to further decrease the number of alarms by increasing the high respiratory rate parameter as well as increasing the SpO2 delay. During the implementation, the median number of false alarms on the floor fell from 95% to 50%. The median time that individual nurses spent addressing frequent alarms decreased from 20 to 25 minutes per shift to 10 minutes per shift, including the time it took each nurse to complete the monitor log. Ninety-five percent (20 of 21) of families reported that alarms were addressed in a timely manner after the implementation.
intervention versus 87% (53 of 61) before the intervention ($P = .43$). Finally, no acute decompensations, code, or staff emergency occurred or were missed because of the CMCP.

**DISCUSSION**

We describe a standardized, team-based CMCP to reduce the number of alarms in a single unit. Implementation of the CMCP resulted in an 80% decrease in the number of alarms per patient day. We sustained a 55% reduction in the number of alarms through human factor–dependent processes such as changing leads, and an additional 25% reduction was accomplished through customization of the monitor settings.

This standardized, patient-centered approach decreased the number of false alarms and the time nurses spent addressing monitor issues. The age-appropriate initial setting of the monitor parameters allowed for a set starting point for all patients, and having the order set in the electronic medical record allowed for proper communication between the nurses and the physician staff. Review of the appropriateness of the parameters on the first day of monitoring allowed for early patient-specific adjustments. Daily review of the monitor parameters, with family and nursing input, allowed for frequent evaluation of the appropriateness and safety of the current parameters. This daily assessment, with anticipation of discontinuation of monitoring, allowed for the timely discontinuation of the monitor.

Daily lead changes can be cumbersome and painful for patients. We discovered that by replacing leads during daily baths, the unpleasantness of the lead change was manageable. By taking advantage of existing habits of the providers, and decreasing the pain experienced by the patient, we maintained an 85% compliance rate with daily lead changes.

Interestingly, in September 2013, our compliance with the CMCP decreased with increased variation. Although we stayed within the control limits of our system, our number of alarms increased at the same time. When the variation improved, so did the number of alarms per monitored day. To improve the sustainability of the CMCP, we review compliance weekly and analyze failures with the nursing and clinical staff. Accountability, with clearly defined roles and responsibilities, helps components of the CMCP to be a part of the staff’s daily responsibilities. We believe that the roles and responsibilities entailed in the CMCP can be applied to most units with cardiac monitor care.

The present study was limited by the lack of a comprehensive patient satisfaction survey before and after our intervention. Our patient questions were limited to the BMT patient satisfaction survey, which asks if nursing staff responded to alarms in a timely manner. Only a small percentage of patients completed the questionnaire, and the results did not show a statistically significant difference. In addition, because implementation of all these processes occurred at nearly the same time, it is difficult to know exactly what intervention made the largest change.

**FIGURE 5**

Number of alarms per monitored patient-day.
We found a significant decrease in the number of alarms per monitored patient-day with the implementation of the standardized CMCP. We believe these efforts have improved safety on the BMT unit by decreasing the number of alarms and the risk of alarm fatigue. With fewer false alarms, the staff can address alarms more promptly. The patients’ and their caregiver’s daily routines are less interrupted by alarms because of the CMCP.

Finally, these efforts have decreased the amount of time the nursing staff spend addressing false alarms on the unit.

CONCLUSIONS
We recommend a team-based approach to cardiac monitor care. Initial parameters should be specific for the patient and evaluated frequently; electrodes should be replaced daily, and monitors should be discontinued when no longer clinically indicated.

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