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Quality improvement initiative for reduction of false alarms from multiparameter monitors in neonatal intensive care unit

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Abstract:

INTRODUCTION: Unnecessary and excessive activation of alarms ("false alarm") in neonatal intensive care unit (NICU) often results in alarm fatigue among health-care professionals, which can potentially result in deleterious effects in sick neonates.

AIMS AND OBJECTIVES: The aim of this study is to reduce the frequency of false alarms from multiparameter monitors (MPM) by 50% from the existing baseline level over a period of 12 weeks.

METHODS: In this quality improvement (QI) project conducted over 1 year (November 2016–October 2017) at All India Institute of Medical Sciences, New Delhi, we collected data on activation of false alarms from MPM (outcome measure) over a period of 2 months in 134 randomly selected observations of 1-h duration (baseline phase [10 days, 20 observations] and developing and testing the changes in five Plan-Do-study-Act (PDSA) cycles over the next 50 days, 114 observations. We also measured the pre- and postassessment of knowledge level in use of MPM among health-care professionals using checklist (process measure). Following that, we continued data collection for next 10 months to check sustenance of the project.

RESULTS: Baseline characteristics including gestation, birth weight, and sickness level did not vary during the study period. The median (range) number of activation of false alarms/hour/MPM was 23 (18–35) in the baseline phase. This reduced to 22 (17–30), 19 (15–30), 16 (14–30), 14 (8–17), and 9 (6–12) at the end of 1st, 2nd, 3rd, 4th, and 5th PDSA cycles, respectively. In sustenance phase, it could be maintained in target range from January 2017 to October 2017.

CONCLUSIONS: Small sustained changes can contribute a lot in continuous QI in decreasing false alarms and subsequent improvement of neurodevelopmental outcomes discharged neonates.

Keywords:

False alarms, multiparameter monitors, quality improvement initiative

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Introduction

Neonates admitted to neonatal intensive care unit (NICU) require continuous monitoring using electronic devices such as multiparameter monitors (MPM), infusion pumps, pulse oximeters, ventilators which are provided with safety alarm limits for better patient care. Although these alarms alert health-care providers (HCPs) about ongoing clinical status of the baby and to take timely appropriate measures, very often there is unnecessary and excessive activation of alarms which are known as false alarms or nuisance alarms.[1,2] False alarms lead to alarm fatigue and desensitization toward true alarms among HCP.[3] Exposure to excessive noise causes tachycardia, hypertension, disturbed sleep, tachypnea,

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bradypnea, and desaturation in preterm neonates. Apart from these, poor performances in Bayley score assessment, hearing loss, and delayed language development were noted in long-term follow-up.[4]

False alarms do happen frequently (up to 80%–90% of total alarm) and cause disruption of patient care.[1,2,5-8] Emergency Care Research Institute labeled alarm hazard as one of the top 10 health technology hazards.[9-12] Being a major health safety issue, the Joint Commission of United States has aptly ordered all hospitals to examine the effects of alarm on patient safety.[13]

Before the initiation of the study, we identified excessive activation of false alarms in our nursery as a problem and measured its magnitude over 10 days. Median number of false alarms was 23/MPM/h, which was a significant problem. Hence, we conducted this quality improvement (QI) study to reduce false alarms in our unit.

Methods

Ours was a QI study (before and after study design) conducted at Neonatal Intensive Care Unit of All India Institute of Medical Sciences over a period of 1 year (November 2016 to October 2017). Our study adhered to the Standards of QI Reporting Excellence 2 (SQUIRE 2) guidelines available freely in the equator network.[14] and methodology was adapted from Point Of Care QI Learner's guide) which has been developed by our institute along with the collaboration of World Health Organization.[15] Being a QI project consent has been waived off by the institute ethics committee.

For better comprehension, the study can be divided into four steps.

Step 1: Identification of problem, team building, and construction of SMART (specific, measurable, achievable, relevant, timely) aim

Study setting and identification of problem

Ours is a 10-bedded Level III and 20-bedded Level II NICU apart from kangaroo mother care and rooming-in unit. The nurse–patient ratio ranges from 1:1 to 1:2 in the Level III unit and 1:2 to 1:3 in the Level II unit. Being a referral center for high-risk antenatal care, approximately 30% of neonates born in our hospital get admitted to NICU at time of birth. Neonates are given care in either radiant warmers or incubators. Babies' vital parameters are monitored using MPM or pulse oximeter. MPM are devices with facility to record multiple physiological parameters simultaneously which include heart rate, oxygen saturation, blood pressure (invasive and noninvasive), and temperature. MPMs were being used during the study period belonging to following manufacturers: Mindray™, Monet™, Covidien™, Nellcor™, Schiller™, Masimo™, and Mediana™. Of the MPMs, Mindray™ was the most common MPM used in 60% babies (16/30) monitored with the same. At any given point of time, approximately 70% of admitted babies in NICU require ventilatory support (noninvasive/CPAP/invasive) and 50% need intravenous medication (antibiotics/sedation/inotrope) or intravenous fluid which are delivered using infusion pumps. Sources for activation of false alarms in our NICU were MPM, pulse oximeter, ventilator, radiant warmer, incubator, and infusion pump. Among these equipment, we planned to target MPM, as it was the most common source for false alarm.

The study flow can be divided into four steps.

Operational definition

For our study, we framed operational definition of true alarm and false alarm. A "true alarm" was defined as the alarm of clinical significance which needs definite action from HCPs, whereas "false alarm" was defined as the alarm which was unwarranted and does not indicate any clinical deterioration of the neonate. Assigned nursing staff was educated to attend the neonate and perform clinical examination whenever alarms were activated and label them as either true or false alarm along with corrective measures for the same.

Team building

Our core team comprised one faculty in-charge who was the team leader, one resident physician who executed the plan, one nurse educator who helped to train other team members, and four staff nurses.

Aim statement

For the study, the SMART aim was to reduce activation of false alarm from MPM/h/bed by 50% from existing baseline over a period of 12 weeks.

Step 2: Analyzing the problem and measuring project indicators

Project indicators

For our study, we defined the outcome measure (primary outcome) as the number of false alarms activation per hour of observation period per bed. The process measure (secondary outcome) was knowledge level (%) before-and-after training in use of MPM among health-care professionals using a common questionnaire. The primary outcome was assessed in each Plan-Do-Study-Act (PDSA) cycle compared to baseline phase. We also planned to measure balancing outcome as number of times alarms were muted by HCP. Some other parameters collected were number of staff nurses who underwent training and certified at the end of the study, number of new leaders created during the study process.

Analysis of problem in baseline phase

The following data were collected in baseline period:

1. Major source of activation of false alarm as well as exact proportion of each alarm
2. Number of false alarm activation
3. Various causes of activation of false alarm (root cause analysis/fishbone analysis)
4. Baseline knowledge of staff nurses to use MPM.

Following 10 days of baseline phase, data were collected in a predesigned pro forma from a randomly assigned monitor (Mindray) for 1 h/day. In baseline period, we identified the major sources of activation of false alarm were MPM (72%) followed by ventilators, infusion pumps, and radiant warmer. For our study, we targeted heart rate and oxygen saturation initially. Nursing staff noted the number of true and false alarms, corrective measures taken by HCP and number of times the false alarms were muted. Various causes of false alarm activation from MPM were identified and analyzed [fishbone analysis, Figure 1]. Various barriers identified (using fishbone analysis) were lack of standard operating protocols to use MPM, unfamiliarity among nursing staff to use MPM, and inappropriate alarm limits for an individual baby. These issues were addressed in implementation phase. We assessed baseline knowledge, attitude, and practice about use of multi-parameter monitor among nursing staff by using a predesigned scoring checklist.

Step 3: Developing and testing changes in implementation phase

A comprehensive package for reduction of false alarms consisted of education of HCP regarding use of interpretation and maintenance of MPM. The team gave one-to-one bedside training and mistakes were corrected. List of nursing staff who underwent formal training to use of MPMs was prepared, and at the end of training, they were asked to answer the questionnaire as part of post assessment. In both baseline phase as well as implementation phase (PDSA 1-4), we collected data of activation of false alarms from MPM of duration 1 h each in two randomly selected NICU beds in daily basis and average of two were entered in Excel sheet. In PDSA 5, frequency of data collection increased to 4/day.

Various key changes proposed and tested in our study were sensitization and training of nursing staff to use MPMs, intensification of training (1:1 teaching), acknowledging the trained staff by certification at the end of training, use of social media platforms such as WhatsApp for dissemination of knowledge, building new team capacity, and establishing unit policy to decrease false alarms. Most important part of education was teaching the HCP regarding setting individualized alarm limits of common vitals such as SpO2 and heart rate. Staffs were educated to set alarm limit of 90%–95% SpO2 for neonates receiving respiratory support with FiO_2 >21% while for those neonates in room air (FiO_2 21%) the upper limit of alarms were increased to 100%. Similarly, for neonates with congenital cyanotic heart disease, we decreased lower limit to SpO2 of 70% for defining hypoxemia. Neonates with severe bronchopulmonary dysplasia on chronic ventilation the lower limit of SpO2 was decreased to 85%. We also adopted similar changes for heart rate monitoring where the upper and lower alarm limits were widened to 100–180/min from existing 110–160/min. These changes

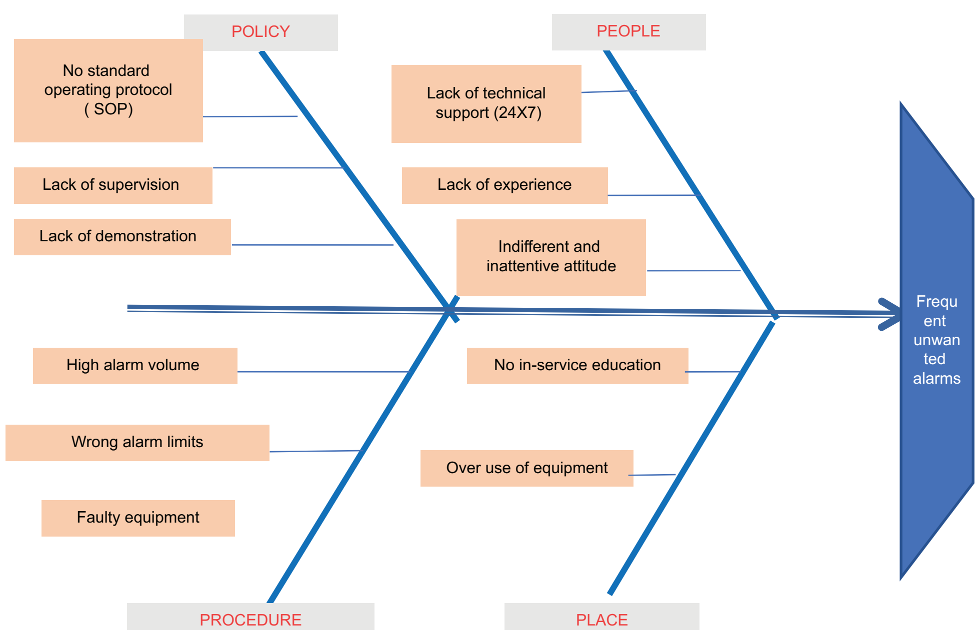

Figure 1: Fishbone analysis of causes of activation of false alarms from multiparameter monitor

were tested as a part of the PDSA cycle and successful plans were adopted [Table 1].

- PDSA 1: Training of HCP regarding use of MPM
- PDSA 2: Intensification of training
- PDSA 3: Team capacity buildup by expansion of team members
- PDSA 4: Dissemination of knowledge by use of social media, sustenance of gained results
- PDSA 5: Inclusion of various other types of MPM.

Combined meeting of team members with nursing staff was conducted every week in the implementation phase to display run charts depicting the data of previous week. In sustenance phase, these meetings were conducted once in a month to discuss the results and constructive bidirectional feedback among team members and nursing staff were exchanged.

Step 4: Sustaining improvement

We planned to continue on-going data collection in sustenance phase. Apart from that, in order to sustain the gained improvement, we created unit policy, which included preparing a skill checklist for alarm management competency. Various components were information on use of MPM, monitoring of alarm, troubleshooting, and common frequently asked questions. Furthermore, we continued conduction of monthly QI meeting and audit.

Data collection and analysis

Data on activation of false alarm for PDSA 1–4 were obtained from 2 MPMs and the data for PDSA 5 collection was obtained from 4 MPMs. Data were collected in predesigned pro forma and entered into MS Excel sheet. Primary and secondary outcomes were plotted as time series graph using Microsoft Excel in separate run charts and various changes (trend, shift) were annotated.

Results

Baseline phase (initial 10 days)

Median (interquartile range [IQR]) number of activation of false alarms and true alarms per hour per bed from MPMs were 23 (18–35) and 6 (1–11), respectively (total 20 observations). Knowledge level among nursing staff to use MPMs assessed by predesigned scoring pro forma was 40% [Figure 2].

Table 1: Details of plan-do-study-cycle

PDSA cycle (time line)	Plan	Do	Study	Act
PDSA 1 (11.11.16-24.11.16)	Training of HCP regarding use of MPM	1.Group teaching, demonstration, counter demonstration on Mindray MPM, 2.Training on use of various components of MPM like HR, SPO_2, ECG and invasive BP monitoring 3.Assessment of knowledge level scores on use of MPM 4.Competency certificate of each staff nurses at end of training 5.data on false alarm was collected	1.Training on less frequently used para meters like ECG, IBP were not welcomed by new nurses who found it difficult to understand , how ever they were prompt in learning use of parameters like HR and SPO_2 2. Median no of activation of false alarms decreased from 23 (18-35)/1hr/bed in the baseline phase to 22 (17-30)/1h/bed 3.Median knowledge score improved from base line 40 (28-67)%, *n*=10 to 61 (55-90)% , *n*=14	Training was focused on HR, SOP_2 first, other parameters like IBP, ECG were dropped
PDSA 2 (25.11.16-01.12.16)	Intensification of training	1.1:1 teaching, 2.Attempt replacement of all faulty MPM 3.Rest same as PDSA 2	1.Median no of activation of false alarms decreased to 19 (15-30)/hr/bed 2. Median knowledge score improved to 84 (60-90) %, *n*=7 3. Replacing all the faulty MPM was not possible within short span due to administrative issues	1.Intensified teaching continued and no further knowledge level scoring was done
PDSA 3 (02.12.16-15.12.16)	Team capacity build up by expansion of team members	Same as PDSA 2, validation of new team members	Median no of activation of false alarms decreased to 16 (14-30)/hr/bed, 4new team members were identified	Plan adopted
PDSA 4 (16.12.16-22.12.16)	Dissemination of knowledge by use of social media, sustenance of gained results	Same as PDSA 3, Use of social media (whatsapp reminder), making alarm limit check as routine policy during shift change hours	Median no of activation of false alarms decreased to 14 (8-17)/hr/bed	Unit policy was build up and plan was adopted
PDSA 5 (23.12.16-29.12.16)	Inclusion of various other types of MPM	As above , increasing frequency and number of MPMs and including on variety of MPMs apart from Mindray,	Median no of activation of false alarms decreased to 9 (6-12)/h/bed	Ongoing training of new staff nurses continues, refreshment training of existing staff continued

Data is represented as median (range). PDSA:Plan-do-Study-Act, HCP=Health-care provider, MPMs=Multiparameter monitors, ECG=Electrocardiography, BP= Blood pressure, HR=Heart rate, IBP=Intra arterial blood pressure monitoring

Implementation phase: Testing the changes

After identification of various causes of false alarms, PDSA cycles were planned and initiated [Table 1]. One of the major barriers was lack of formal training to nursing staff regarding use of MPMs and ignorance about minute facts. Hence, nursing staff were trained to use MPMs. Various ideas implemented through five PDSA cycles are shown in Table 1.

There were a total of 114 observations. At the end of five PDSA cycles (50 days), the median number of activation of false alarms decreased to 9 (6–12)/h of observation/bed. Similarly, the average knowledge level of use of MPM improved to 84 (60%–90)% by the end of third PDSA cycles. However, the median number of activation of true alarms remained static throughout the study period 5 (IQR 4–8). As these were indicative of true sickness of baby and the system change had minimal effect on true alarms. The PDSA cycles have been explained in detail in Table 1 and Figures 2, 3.

At the end of five PDSA cycles (50 days), the median (IQR) number of false alarms decreased to 9 (6–12)/h/bed. The average knowledge level of use of MPMs improved to 84 (60%–90)% by the end of third PDSA cycle. However, the median number of activation of true alarms remained static thought study period 5 (IQR 4–8). As true alarms were indicative of true sickness of baby and the system change had minimal effect on true alarms.

Sustenance phase

We were able to sustain the result of our QI in post implementation phase by ongoing training and adhering to the created unit policy. Following 10 months of implementation of QI, the median number of activation of false alarm reduced to 3/h/bed (November 16–October 17) [Figure 4].

Balancing outcome

One of the balancing outcomes which the QI team found was work pressure on the nurses to keep NICU noise free which resulted in silencing of both true alarms and false alarms at times. As this was detrimental for baby, we conducted formal education module to nursing staff to remove fear.

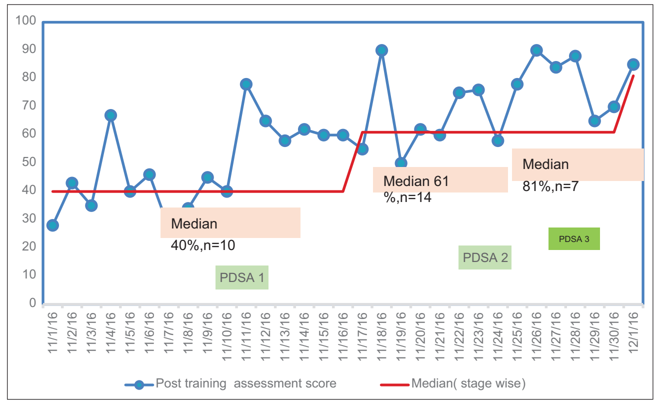

Figure 2: Process measure run chart showing assessment of knowledge of use of multiparameter monitors

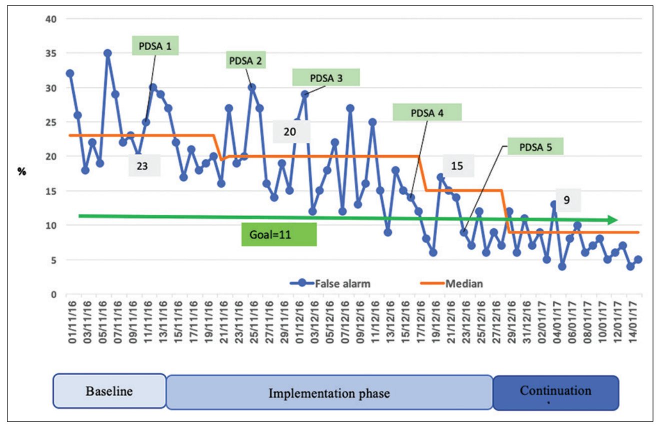

Figure 3: Run chart showing activation of false alarm/hour/1MPM

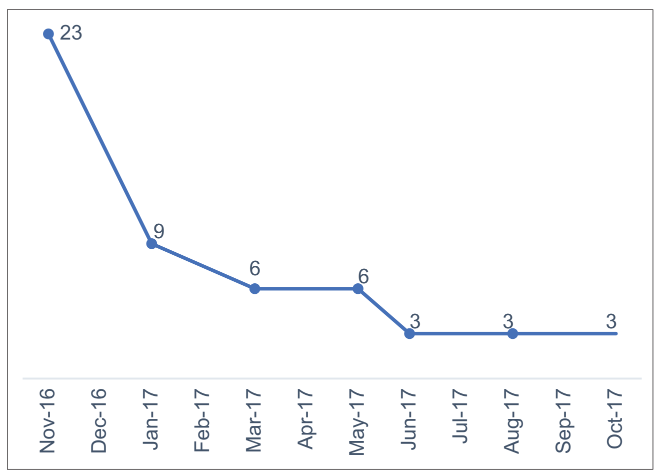

Figure 4: Run chart on activation of false alarm/hour/1MPM in sustenance phase

Discussion

In the current project, we were able to achieve our goal of reduction of activation of false alarms by 50% from baseline level over a period of 2 months by applying principles of QI. We were able to sustain it in next 10 months by ongoing staff education and establishment of standard operative protocols for operation of MPMs.

Bedside alarms are important and lifesaving for patient monitoring and safety. Excessive activation of false alarm is a common problem faced by many NICUs. The problem of false alarms and its effect has been extensively studied.[1,2] However, it is challenging to keep false alarms under control due to lack of standardized methods.[2] Although "smart alarms" analyzing activation of alarm with patients' clinical condition may be a good solution for reduction of false alarms, their availability in low-middle-income countries is inadequate.[16] In the absence of advanced solutions, there is a pressing need for correction in the existing system by applying principles of QI.

In a QI project conducted at NICUs of Connecticut, Johnson *et al*. had shown reduction of false alarms without increasing incidence of hypoxemia by making appropriate changes in oximeter alarm settings which included revision of alarm limits, alarm delays, and age-specific alarm profiles.[17] Goel *et al*. had shown in their study that implementation of data-driven, age-stratified vital sign parameters leads to reduction in the frequency of heart rate alarms.[18] By using multiphase noise reduction QI intervention, Chawla *et al*. had reduced noise levels in their NICUs significantly.[19] Similarly, we were able to decrease the activation of false alarms from MPMs by 50% from baseline by conducting multiple rapid learning PDSA cycles incorporating several changes of idea like training of nursing staff to use and interpret heart rate (HR), saturation (SPO_2), acknowledgement of training by certification, creating and utilizing new team members for monitoring and propagation of training displaying the results in form of run charts in each monthly QI meeting, use of low cost reminders (social media like Whatsapp) for dissemination of knowledge, establishing unit policy. Similar changes were achieved by adopting to changes of idea through various PDSA cycles in reduction of false alarms.[1,2,8,20]

In our study, parameters HR and SpO2 were the most common source of false alarms activation. Similar observations have been seen in previous studies as well.[1,21,22]

Strength and limitations

The strength of our study is that it is one of the few studies from a resource-limited setting, attempted to reduce false alarms in a NICU using interventions that are appropriate for local health-care facility.

Our study had few limitations too. Being a small single-center study, successful change of ideas are context specific and they may not be generalizable to other health care facility. We could not measure balancing outcomes such as number of times alarms were muted by nursing staff. We did not assess other sources of false alarms such as electrocardiogram monitor and invasive blood pressure, as we found MPMs were the major sources of activation of false alarms in baseline assessment. Presence of an observer for measurement process itself might have resulted in decrease in false alarm (Hawthorne effect).

Conclusions

We demonstrated feasibility and sustainability of a simple QI approach for decreasing activation of false alarms in our nursery. This could be achieved within existing resources without addition of extra workforce.

What is already known

Unnecessary repeated activation of false alarm can cause alarm fatigue among health-care worker and associated bad neurodevelopmental outcome among the NICU babies who graduate from the nursery.

What this study adds

By doing small sustained changes through principles of QI, it is possible to decrease false alarms.

Acknowledgment

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Nil.

Conflicts of interest

There are no conflicts of interest.

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