Improving Clinical Alarm Management: Guidance and Strategies

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Abstract

This article focuses on the type of problems that lead to false or nonactionable clinical alarms and the type of data that can help identify which of these alarms are most prevalent in specific units in healthcare facilities. The process of identifying necessary data is first described, as this activity will drive later choices on capturing data. This article also discusses how to use the data collected in alarm reports to help determine which alarms should be targeted first for improved management in a pilot environment. Suggestions are provided on how to reduce false and nonactionable alarm signals and how to monitor to ensure no untoward consequences occur from new alarm default settings. The information provided here can be individualized to hospitals and units to enhance alarm management with physiological monitor alarms. It also can be adapted to reduce nonactionable alarm signals occurring from other medical devices.

The experiences and lessons learned from the authors and other members of the AAMI Foundation National Coalition for Alarm Management Safety are described in this article. Most of these lessons resulted from quality improvement projects conducted by coalition hospitals. This article serves as the vehicle to move this collective learning into the body of literature for the clinical and healthcare technology management (HTM) communities. It is intended to provide practical advice and solutions that can be readily adopted.

Hospitals rely on alarm-equipped medical devices to provide appropriate care to patients, and alarm management is a critical patient safety issue and goal. According to The Joint Commission National Patient Safety Goal (NPSG) on clinical alarm safety,[1] hospitals are tasked with implementing an alarm management protocol and educating clinical staff. This article provides information for alarm management committees, which have been formed at many hospitals in response to the NPSG. Information on the types of professionals to consider for inclusion on alarm management committees can be found in the AAMI Foundation's *Clinical Alarm Management Compendium.*[2]

Factors Contributing to Nonactionable Alarms

Alarm signals are triggered by multiple factors, both clinical and nonclinical. A high volume of alarm signals that are false or nonactionable can result in staff taking inappropriate actions, such as silencing or ignoring the alarm signals, as evidenced by and contributing to alarm fatigue. A false alarm is defined as an alarm sound that occurs when no valid triggering event has taken place in the patient or equipment (e.g., poor electrode-to-skin contact producing artifact).[3] A true-positive alarm condition is when a valid triggering event occurs in the patient or equipment.[3] A nonactionable alarm signal is not defined in

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any standard. However, for the purpose of this article, it is defined as a true alarm that is correctly sounding based on how the default parameters are set, but for an event that has no clinical relevance or requires no clinical intervention.

Determining the causes of false and nonactionable alarm signals and systematically addressing these causes can have a positive effect on patient safety.[4] Common causes of false and nonactionable alarm signals include the following:

False alarm signals due to artifact.[5] 1) Waveform artifact/electrocardiogram (ECG); contributing causes may include a) poor electrode prep and placement procedure; b) no schedule for changing electrodes being established or not adhering to a regular schedule for changing electrodes; c) lead wires being broken. 2) Artifact in the SpO_2 waveform; contributing causes may include a) sensor placement not being secure; b) cables being disconnected or not seating firmly or a damaged sensor; c) patient conditions that cause difficulty in signal acquisition (e.g., skin pigmentation, nail polish, low perfusion states).

Nonactionable alarm signals due to the levels set for parameter defaults ("true alarms" that may not be clinically relevant).[2,6–10] 1) The hospital may still be using manufacturer factory default settings throughout the facility and has not established appropriate default settings for units (e.g., default settings are set for high sensitivity but low specificity). 2) Alarm priority settings (i.e., high, medium, low) have not been set appropriately. 3) Hospital has not established default alarm settings/profiles for specific patient populations served (e.g., cardiac, pediatrics, chronic obstructive pulmonary disease). 4) Hospital has not created a policy, accompanied by appropriate staff competency training, empowering nurses to further customize alarm settings based on specific individual patient needs.

Obtaining Data from Medical Devices

Data are needed to determine which alarms, in relation to specific patient populations and hospital units, are causing the most false or nonactionable alarms. This knowledge is required before changing default parameter settings or making other improvements, such as enforcing proper electrode management, incorporating alarm delays, changing alarm limits and levels, or deciding to switch off an alarm signal. Clinical improvements can be made only after a baseline alarm assessment has been established. Optimizing alarm signals requires the development of repeatable processes; otherwise, solutions may not translate to other clinical care areas.[4]

To make a meaningful reduction in alarm signals, data should be collected to document baseline alarm conditions in the unit-care environment. Starting with a simple baseline and progressively building from there is recommended. Baseline data to be collected include the current default parameter settings, frequency of alarm customization of default parameter settings, criticality of the alarm conditions, and number and type of alarms per patient per day. Using alarms per bed per day based on the total bed count (i.e., occupied and unoccupied) can be a problem in that beds are not always occupied; therefore, a metric based on occupied bed count per day is preferable, especially for units with variable census.

Creating the Data Report

How does the hospital alarm management committee determine which of the previously described types of alarm signals (false and nonactionable) exist in the facility? This can only be done by intensive tracking and trending of the data. We recommend that the committee determine the current and future alarm management data needs of its organization, before any alarm data extraction or before speaking to a vendor about the types of physiologic monitor alarm reports that may be available. The data collected should be meaningful and assist with achieving measurable clinical outcomes that will be of use to the stakeholders in the organization and positively affect patient care.

The stakeholders in this endeavor should include point-of-care professionals who work with healthcare technologies that use alerts and alarm signals to indicate whether patient assistance is needed. Included in the group are direct report managers of nursing professionals and senior leadership staff

monitoring risk, patient safety, and quality improvement. The alarm committee should ask these stakeholders: "If you had perfect alarm reports for medical devices, what would you want to accomplish and how would these reports help you meet those goals (i.e., how might access to the desired alarm data influence clinical practice)?"

Each group of stakeholders, such as point-of-care nurses, critical care nurses, respiratory therapists, charge nurses, nurse managers, clinical nurse specialists, nurse administrators, intensivists, hospitalists, and patient safety/quality/risk management professionals, may need different information about alarm signals in the reports that will be made available to them. The stakeholders should consider how information about the number and types of alarms that are occurring in their work environments could affect:

- Staffing.
- Workflow analysis or process review.
- Alarm settings management.
- Immediate impact on patient care. For example, an "alarm flood" condition is when 10 or more alarms occur in 10 minutes, which is more than a human operator can be expected to respond to effectively.[12]
- Protocol management/process review.
- Metric comparison against peers.

Understanding what stakeholders want to achieve in these areas will help them determine what data need to be included in the reports. Each group for each specialty area should consider which of the following pieces of data will help them accomplish the goals they want to achieve.

Summary reports. Typically most useful to the nurse managers and the alarm committee, summary reports may include:

- Alarm descriptions (what caused the alarm).
- Number of alarms/patient/day by alarm description.
- Number of alarms by nurse.
- Time of day and shift.
- Number and type of alarms by department/unit.
- Number and type of distribution of alarms by patient.
- Alarm duration (average and/or actual).

- Average time: alarm duration and nursing response.
- Number of events (summary of simultaneous multiple parameter alarms).
- Number of alarms by parameter.
- Number of alarm limit changes (totals and averages) by bed.

Alarm/event reports. Typically most useful to the nurse managers and risk managers when reporting an incident or when working on the root-cause analysis of a particular incident, as well as to the alarm committee. These reports may include:

- Alarm duration (average and/or actual).
- Alarm start and stop times.
- Number of alarm limit changes.
- Number of times the alarms are silenced or paused.
- Number of times patient monitor is placed in a standby mode with monitoring suspended.
- Number of times alarms are acknowledged.
- Number of times alarms receive actual intervention (i.e., some adjustment to the patient's care); difficult to obtain.
- Patient physiological information from the time before and after the alarm.

Real-time data or metrics available for dashboard reporting. Typically most useful to point-of-care nurses and their managers, as well as to the alarm committee. These reports may include:

- Alarm floods by unit.
- Alarms/nurse unit.
- Alarms/bed/shift or alarms/bed/day.
- Time of day for most alarms.
- Time of week for alarms (weekdays versus weekends).
- Type of alarm sounding most often (e.g., SpO_2).

Other data elements to consider collecting may include:

- Do the alarms call to actionable clinical interventions? How is this clinical intervention related to patient safety?
- Should other interruptions, such as nurse call alerts, labs, orders, or text messages be tracked?

Each group of stakeholders may need different information about alarm signals in the reports that will be made available to them.

When hospitals negotiate contract renewals with vendors or purchase new physiologic monitors, it is recommended that usable and meaningful data reports be included in the contract, as well as how often the vendor can provide the reports.

Methods for Acquiring Alarm Data

After the data needs of the stakeholders have been determined, the next step is to obtain the data that will populate the reports. Getting the data out of the physiological monitors can be challenging, especially if the monitors are more than 8 to 10 years old. Older monitors often may not have the capability to save data that can be easily downloaded to create the reports. Newer monitors typically have the capability to store alarm data that can be exported to spreadsheets to create alarm reports, and many of the newest monitors have software that can directly generate alarm reports, which sometimes can be customized for the hospital's individual needs. Discussing the current monitors' capabilities for downloading alarm data and creating reports is critically important. Retrieval of alarm data varies according to the model and functionality of specific monitors. The hospital should confer with the manufacturer on available options and select the one that fits best according to internal resources.

One option involves working with the monitor vendor to to obtain data from older models of monitors, a second option is to purchase a new software package that provides alarm reports, and a third is to purchase new monitors. If the medical device vendor pulls the required information from the older monitors, they should work with the hospital to create useful reports. This may take several weeks each time a request is made for a certain time period of alarm monitoring, and vendors may charge for this service.

The vendor may have a software upgrade that is compatible with the hospital's current model of monitor that can be installed to produce ongoing alarm data/reports (vendors typically will charge for the software upgrade), or the hospital may decide to purchase new monitors with viable report capabilities. Regardless of which method the hospital chooses, using the criteria established in the needs assessment for each specialty area (described above) is important. Speak with the vendor(s) about how they achieve meeting those criteria in their alarm reports. When hospitals negotiate contract renewals with vendors or purchase new physiologic monitors, it is recommended that

usable and meaningful data reports be included in the contract, as well as how often the vendor can provide the reports. When purchasing a new software package to create reports or when purchasing new monitors, it is important for hospitals to ask the vendor what level of customization can be provided in the alarm reports and how well the canned or customizable reports meet the predetermined stakeholder needs.

In addition, the hospital may want to consider asking the vendor the following questions about the new software or monitors: What data are available in the reports (e.g., physiologic alarms, technical alarms, status messages)? How often can reports be run? At what intervals can the reports be generated? Can hospital staff run the reports? Are the reports finalized and presentable with meaningful analysis, allowing for a clinically relevant summary of the findings? Can the data be compared side-by-side in terms of month and years, in order to identify measurable improvement or need for improvement? How many different systems or alarm sources are available from the reports?

A second option is for the hospital to work with a third-party vendor to create needed reports and triage alarm signals. Alternatively, the hospital could purchase middleware (devices that send physiologic monitoring alarms to phones or alarm management reporting systems that interface with the bedside monitors) and work with the middleware vendor to create reports and triage alarms.

If a decision is made to implement this second option, the hospital should use the criteria established in the needs assessment for each specialty area (described above) to talk with the vendor(s) about how they achieve meeting those criteria in their alarm reports. In addition, all of the questions presented for the first option should be investigated with the third-party vendor.

A third option is for the hospital HTM and information technology (IT) departments to export the data from the device server and create reports. This is labor intensive. Hospitals might consider having their monitor or middleware vendor train HTM staff to be able to obtain data reports. Depending on the size

of the organization, the task of data extraction may require more or less manpower.

When hospitals do not have the resources to obtain alarm data from monitors, a fourth option would be to use low-tech methods for obtaining useful data. For example, the hospital may survey nurses in targeted units to determine which medical devices and physiological monitor conditions are producing the most nonactionable alarm signals. Alternatively, they may manually record alarm-related information (e.g., number of alarm signals, duration of the alarm signals, most common types of alarm conditions, patient alarm conditions versus technical alarm conditions, clinician response time to alarms) during unit observations and rounding. It can be helpful to meet with nurse managers and unit nurses for a daily huddle to discuss specific alarm management problems that occurred during the previous shift.[6]

Depending on how data are being collected, the frequency of reporting may vary. For example, when organizations create their own reports, the data collection and analysis may be difficult, therefore leading to more episodic reporting time frames. If organizations chose to work with a third-party vendor, reporting timelines may be much more regular (e.g., weekly or monthly).

Improving the Alarm Management Process

Armed with the data collected from the monitors, decisions can be made regarding which alarms to address first and how best to reduce the number of false and nonactionable alarms. To date, no national standards describe alarm default parameter settings. Multidisciplinary alarm management teams should look for opportunities to improve alarm management and reduce the likelihood of alarm fatigue by basing changes on their specific situations and by using data from alarm reports to drive meaningful change. Study the alarm report data to determine those alarms that are "bad actors" and where substantial improvement can be obtained by making small but meaningful changes.[2,7] Nonactionable alarm signals can be reduced by focusing on the following areas:

Alarm settings, limits, and delays[2–11]
- Establish appropriate (e.g., pediatric versus adult) default settings for hospital unit and patient population.
- Turn off duplicative alarms.
- Ensure alarm priority (i.e., high, medium, low) is set to actionable levels.
- Review high/low threshold limits and other settings.
- Small changes, such as decreasing a SpO_2 lower limit by 1 point, can have large effects on reducing nonactionable alarm signals.
- Consider using alarm signal delays to allow for alarm autocorrection (e.g., SpO_2 and ST alarms).
- Consider using secondary alarm notification devices to ensure alarm audibility.
- Consider using alarm escalation to increase alarm priority level.

Clinical population[2,6–11]
- Establish default alarm settings/profiles based on patient population served (e.g., cardiac).
- Create a process to customize alarm settings based on individual patient needs.

Staff education[2,6–11,13]
- Educate clinicians on their role in alarm management.
- Ensure staff are trained and competent in recognizing and troubleshooting equipment alarm signals.
- Empower staff to manage nonactionable alarms by changing limits to actionable levels (based on policy and "standing" orders).
- Encourage staff to review trend data for repetitive alarms, especially during sleep. A perceived 'false' alarm may be a sleep apnea patient with multiple clinically-relevant alarms who wakes up and self corrects when the nurse enters the room.

Patient education[14]
- Educate patients and families about the physiologic monitoring system and their role in patient safety and alarm management.
- Encourage patients and families to notify staff when an alarm signal is not being addressed in a timely manner.
- Consult with other hospitals to determine where they have set their default physi-

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ologic monitor settings. The *Clinical Alarm Management Compendium* includes data from 17 hospitals showing how they have adjusted alarm default settings).[2]

The following area should be considered if the data reveal several false alarms resulting from artifact.[5]

Waveform artifact/ECG/SpO$_2$
- Review proper skin and electrode prep and placement procedure.
- Maintain regular schedule for changing electrodes.
- Inspect reusable lead wires for intactness and replace if indicated.
- Consider use of disposable lead wires.
- Check sensor placement and adhesion.
- Inspect cables for disconnections, frayed wiring, etc.
- Review schedule for routine changing of electrodes and cables.

Test all changes in a small pilot and use a quality improvement rapid-cycle change approach to make modest changes to monitor alarms based on evaluation of data and discussion with staff/leadership. After making changes and monitoring for several months, repeat the process to measure sustained improvement. This is an active, ongoing performance process to improve the care and safety of patients. It is not a one-time event that will simply meet the NPSG. The data should be used to improve care/outcomes and to improve patient care and the nursing experience.[3]

Vendors/IT may charge to make changes in settings on alarm default settings. This can be a time-consuming process that has to be done for each monitor. If the patient room is occupied, the patient should be placed on a portable monitor while the default parameter changes are being made. Some vendors can change default settings globally.

Any changes to alarm parameters or default settings, once agreed upon by the alarm committee, should be clearly communicated to all clinicians in the department and education provided to the point-of-care clinicians. Communication should be documented, and consistent staff training should be conducted. It is important for nurses to realize that many

of the nonactionable alarms will no longer exist when the new parameters are put in place and that they must respond quickly to the newly adjusted alarms, which have been set to actionable levels.

Monitoring for Outcomes
Using a clinically relevant process to ensure no negative patient outcomes result from alarm parameter changes should be a focus. One hospital reported that its medical intensive care unit is used to test changes to alarm parameters. This unit was selected due to high variability in the patient population, as well as a consistent high census and case mix index. Each time a new default is selected for change, 11 days of data are collected as a baseline during one month, focusing on alarms per bed per day by alarm type. These data are compared with those from the following month after the test of change has been implemented, with post–data collection consisting of another 11 days of data. Staff are educated on the test of change prior to implementation. The results of the test of change are shared with the multidisciplinary alarm steering committee, and decisions are made on whether to implement changes in other intensive care units (personal communication, P. Cosper and M. Zellinger, March 2016).

The following examples also demonstrate how hospitals are monitoring to ensure changes to reduce alarm fatigue do not have unanticipated negative patient outcomes:
- Monitoring for noise level in the unit[2]
- Surveying patient satisfaction and nurse satisfaction following changes[11]
- Evaluating incident reports to determine if issues are the result of changes to alarm management[2]
- Convening regular safety huddles with staff (e.g., daily rounding teams, individual staff) to talk about how changes are perceived and if changes are causing untoward effects[6]
- Monitoring for any increase in rapid response calls, intensive care unit transfers, codes, etc., to determine if parameter changes caused a patient condition to be missed

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Conclusion

Rapidly advancing technology holds great promise for improving alarm management and patient care. Medical equipment vendors, third-party middleware and analytics vendors, and hospitals are implementing new and different solutions to monitor, report, and manage alarms from devices. "Smart monitors," which are able to analyze multiple alarm parameters, are being developed, as is the ability to streamline analytics. Middleware integrations that send alarms to phones or alarm management reporting systems that interface with the bedside monitors, as well as other interruption-driven devices or system (e.g., ventilators, nurse call, lab, computerized physician order entry), also are being developed. This ecosystem of innovation and integration has the capability to help improve clinical workflow while reducing alarm burden on staff.

Although some hospitals are on the forefront of this wave of technology, other hospitals do not have the resources to implement these technology-heavy solutions. Regardless of the resources available to individual institutions, the alarm management field should continue to move in the direction of reducing alarm fatigue, which will increase patient safety and improve both nursing and patient satisfaction. ∎

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