Customizing Alarm Limits Based on Specific Needs of Patients

Maria Cvach, Melanie Kitchens, Kevin Smith, Patricia Harris, and Marilyn Neder Flack

Medical device alarms are frequent, alerting for false and/or clinically nonactionable physiologic monitor conditions up to 99% of the time.[1] In 2014, the AAMI Foundation created a think tank of national experts and industry leaders, called the National Coalition for Alarm Management Safety. Its purpose was to define best practices for reducing unnecessary alarms, thereby decreasing the likelihood of alarm fatigue, and to facilitate rapid knowledge translation for specific alarm-related problems.

Despite efforts to control alarms by altering manufacturer presets, ensuring daily electrode and skin hygiene, and implementing other recommendations to reduce nonactionable alarm signals, coalition members agreed that a small number of patients typically are responsible for triggering most alarm signals. However, little evidence supports this assertion. This article describes the work of a team assigned by the National Coalition for Alarm Management Safety to evaluate and make recommendations regarding this issue.

This article is divided into three parts. Part I seeks to characterize alarm data from several coalition hospitals to determine 1) which hospital units produce the most alarm signals, 2) what type of alarm signals are most prevalent, and 3) whether the majority of alarm signals are triggered by a minority of patients. Part II offers recommendations for reducing monitor alarms when frequent alarms occur, and Part III provides tips for reducing frequent alarms.

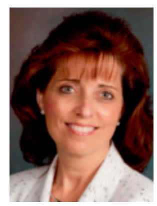
Part I: Characterizing Alarm Signals

During an AAMI alarm coalition meeting in April 2014, members postulated that the majority of monitor alarms are caused by a minority of patients. To analyze this problem and determine characteristics of alarm signals in various hospital units, coalition team members were tasked with examining monitor alarm data at their facilities. Because each hospital and health system has different monitoring equipment and physiologic monitoring default presets, contrasting and comparing data among them is difficult. Thus, common themes and trends found in data from a large health system (36 hospitals), a small health system (two hospitals), and a large academic medical center (all located in the United States) are reported.

Quantity and Distribution of Alarms

A convenience sample of data wase analyzed for distribution across multiple settings, including telemetry, intensive care units (ICUs), intermediate care (IMC/step-down) units, pediatrics, and emergency departments. Tables 1 and 2 illustrate the quantity and distribution of monitor alarms by unit type, for the large and small health systems, respectively, during a 1-year time frame (2015). Given the large number of telemetry beds in most hospitals, it is not surprising that the greatest quantity of monitor alarms occurred in telemetry units, followed by ICU and IMC/step-down units.

About the Authors



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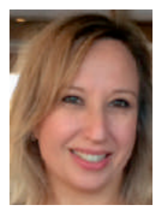

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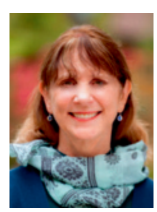

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As noted earlier, each system uses different physiological monitors; therefore, the alarm reports produced are in different formats. However, each format demonstrates that the quantity and type of monitor alarm signals differ by unit population (e.g., coronary care unit, medical ICU, pediatrics).

To further demonstrate this point, alarm signals were trended for 1 week in a large academic medical center. Figure 1 illustrates the number of ICU, IMC, and telemetry alarm signals generated by unit type and average number of beds reporting data. It is evident that certain care units exhibit more monitor alarm signals than others. For instance, during the week in which sampling occurred, the cardiology care unit shown in Figure 1 generated more monitor alarm signals than the surgical ICU. It should be noted, however, that the number of alarms in this hospital is highly dependent on 1) monitor default presets, 2) physician notification parameters, 3) nurse autonomy in customizing monitor alarms, and 4) use of monitor alarm features such as patient profiles and alarm delays. In their efforts to reduce nonactionable alarms, these data may help hospitals prioritize which units to address first.

Next, the team looked at the alarm data from the three coalition hospital systems to determine what types of alarm signals occur most often from across all unit types. The most prevalent monitor alarm signals relate to threshold breaches (e.g., high and low heart rate [HR], low peripheral capillary oxygen saturation [SpO_2]) and technical alarms (e.g., leads off, poor signal) (Tables 3 and 4). Arrhythmia alarms (e.g., bradycardia, tachycardia, ventricular tachycardia) account for a much smaller proportion of alarm signals. Two strategies that may help reduce unnecessary monitor alarm signals are changing manufacturer factory-set alarm presets to reasonable unit-based alarm limit presets and being mindful of electrode and skin hygiene.

In addition, alarm data were broken down by specific care units to determine whether a difference existed in the distribution of alarm signals (Tables 5 and 6). The most prevalent type of monitor alarm signals found in a pediatric ICU environment are SpO_2, high HR, and technical in nature (e.g. poor signal, leads off); whereas the most prevalent type of monitor alarm signals for adult telemetry units are high and low HR and technical alarms (e.g., cannot analyze, ECG leads off, poor signal).

Monitoring of alarm data from a large academic medical center's cardiology care unit during 1 week demonstrated that ST

Unit Type	Total No. Alarms
Adult telemetry	31 million
Adult step down	12 million
Adult critical care	7 million
Emergency department	5 million
Neonatal intensive care	3 million
Pediatric telemetry	1 million

Table 1. Distribution of monitor alarms, according to unit type, for a large health system during 2015

Unit Type	Total No. Alarms
Adult telemetry	15,216,000
Adult critical care	1,308,000
Neonatal intensive care	223,000
Pediatrics	119,000

Table 2. Distribution of monitor alarms, according to unit type, for a small health system during 2015

Alarm Type	Total No. Alarms
High HR	10,933,600
Low HR	7,048,727
Poor signal	5,587,127
Low SpO_2	2,843,165
Cannot analyze ECG	2,724,739
Desaturation	2,523,361
SpO_2 low perfusion	2,075,860
ECG leads off	2,005,953
Tachycardia	1,774,312
Irregular HR	1,140,023

Table 3. Top 10 physiologic monitor alarms, according to alarm type, for a large health system during 2015. Abbreviations used: ECG, electrocardiogram; HR, heart rate; SpO_2, peripheral capillary oxygen saturation.

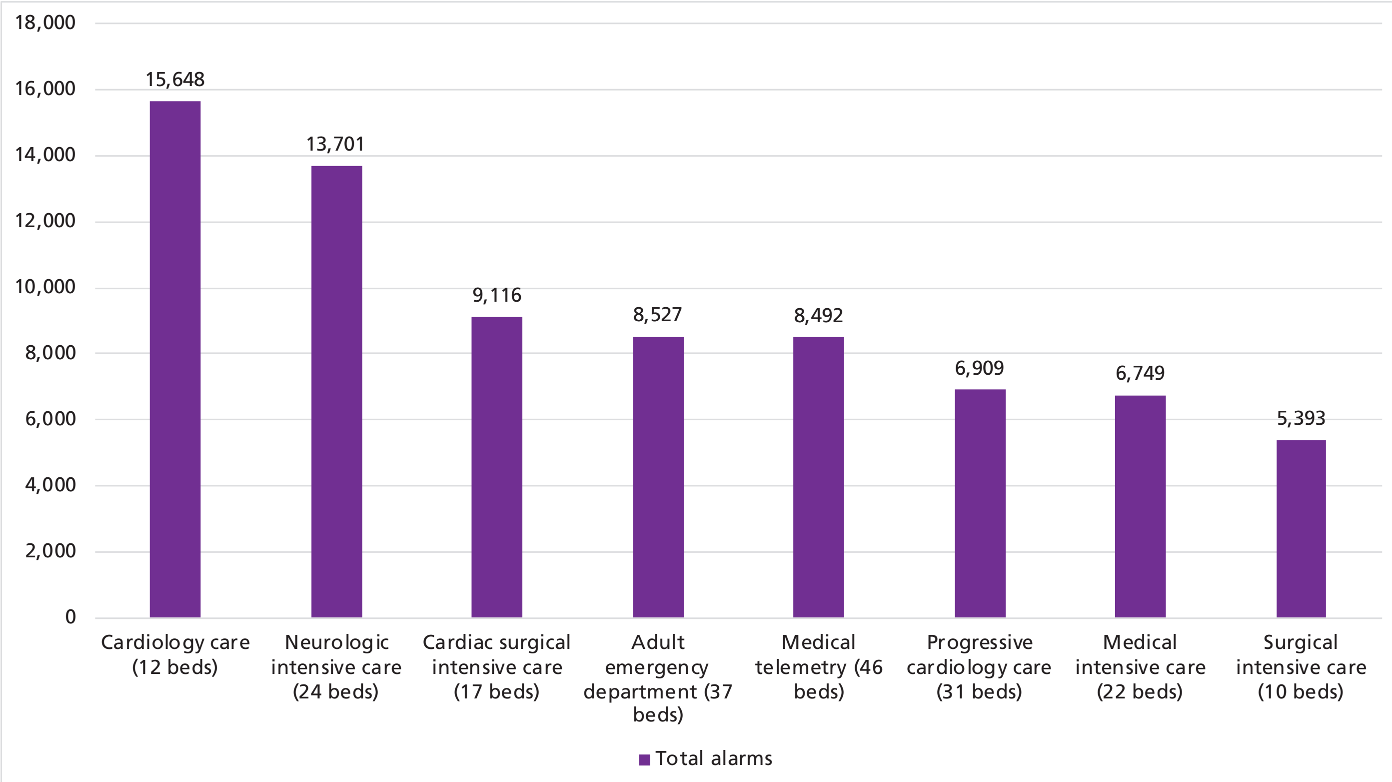

Figure 1. Total monitor alarm signals trended for 1 week at a large academic medical center. The average number of beds appears in parentheses.

Alarm Type	Total No. Alarms
Tachycardia	33,176,641
High HR	2,600,306
SpO_2 probe	2,104,914
PVC high	1,839,122
Low HR	1,814,454
Bradycardia	1,692,264
No telemetry	1,133,484
Lead failure	771,953
SpO_2 low perfusion	564,537
VT high	465,457

Table 4. Top 10 physiologic monitor alarms, according to alarm type, for a small health system during 2015. Abbreviations used: ECG, electrocardiogram; HR, heart rate; SpO_2, peripheral capillary oxygen saturation; VT, ventricular tachycardia.

Alarm Type	Total No. Alarms
Oxygen desaturation	77,426
Poor signal	57,777
High HR	40,688
ECG lead off	21,094
SpO_2 low perfusion	17,555
Cannot analyze ECG	16,682
Low HR	14,605
Tachycardia	9,989
Low SpO_2	6,791
Irregular HR	1,790

Table 5. Top 10 pediatric intensive care unit monitor alarms for a large health system during 2015. Abbreviations used: ECG, electrocardiogram; HR, heart rate; SpO_2, peripheral capillary oxygen saturation.

Alarm Type	Total No. Alarms
High HR	5.19 million
Low HR	4.06 million
Cannot analyze ECG	1.82 million
Low SpO_2	1.35 million
Tachycardia	1.19 million
ECG leads off	1.11 million
Irregular HR	0.52 million
SpO_2 low perfusion	0.47 million
Poor signal	0.43 million
Desaturation	0.36 million

Table 6. Top 10 adult telemetry monitor alarms for a large health system during 2015. Abbreviations used: ECG, electrocardiogram; HR, heart rate; SpO_2, peripheral capillary oxygen saturation.

alarms were the most prevalent, followed by apnea, SpO_2, blood pressure (BP), and HR alarm limit threshold breaches (Figure 2).

Lessons learned. These data demonstrate that the number and type of alarm signals vary by care unit, regardless of the size of the system. Therefore, setting a single set of default presets across an entire hospital or healthcare system will not account for population differences and are likely to cause nuisance alarms. Alarm presets should account for unit and population differences (e.g., ICU, IMC, telemetry, pediatrics).

Alarm limit threshold breaches are responsible for the majority of alarms signals. Selecting reasonable alarm limit presets for vital signs (e.g., BP, HR, SpO_2) will help reduce nonactionable alarms. Evaluating a unit's alarm data helps identify frequent sources of alarm signals. Setting monitor default presets based on evaluation of alarm data is the first step of any alarm management plan.

The majority of patients on a given unit typically have fewer than average alarms/bed/day and a smaller percentage of patients have greater than average alarms/bed/day.

Do a Minority of Patients Cause Most Alarms? Alarm data often are reported as average alarms/bed/day, average alarms/bed/hour, or average alarms/patient/day. Using averages to measure alarms is very deceptive and leads one to believe that alarm signals are evenly distributed across all patients. This is not the case. In fact, the majority of patients on a given unit typically have fewer than average alarms/bed/day and a smaller percentage of patients have greater than average alarms/bed/day. For example, as shown in Table 7 (from one of the 36 hospitals in the large healthcare system), three patients accounted for approximately 83% of the 719 monitor alarms. Calculating the unit's average alarms/bed/day yields 45 alarms (719 alarms/16 patients = 45). However, most patients did not have 45 alarms/bed/day. Only three of the 16 patients exceeded the unit average, whereas 15 patients had less than the unit's average.

In another example from one of the units in the two-hospital healthcare system, the data demonstrated a cardiac telemetry unit's average alarms/bed/day as 126 (5,711/45)

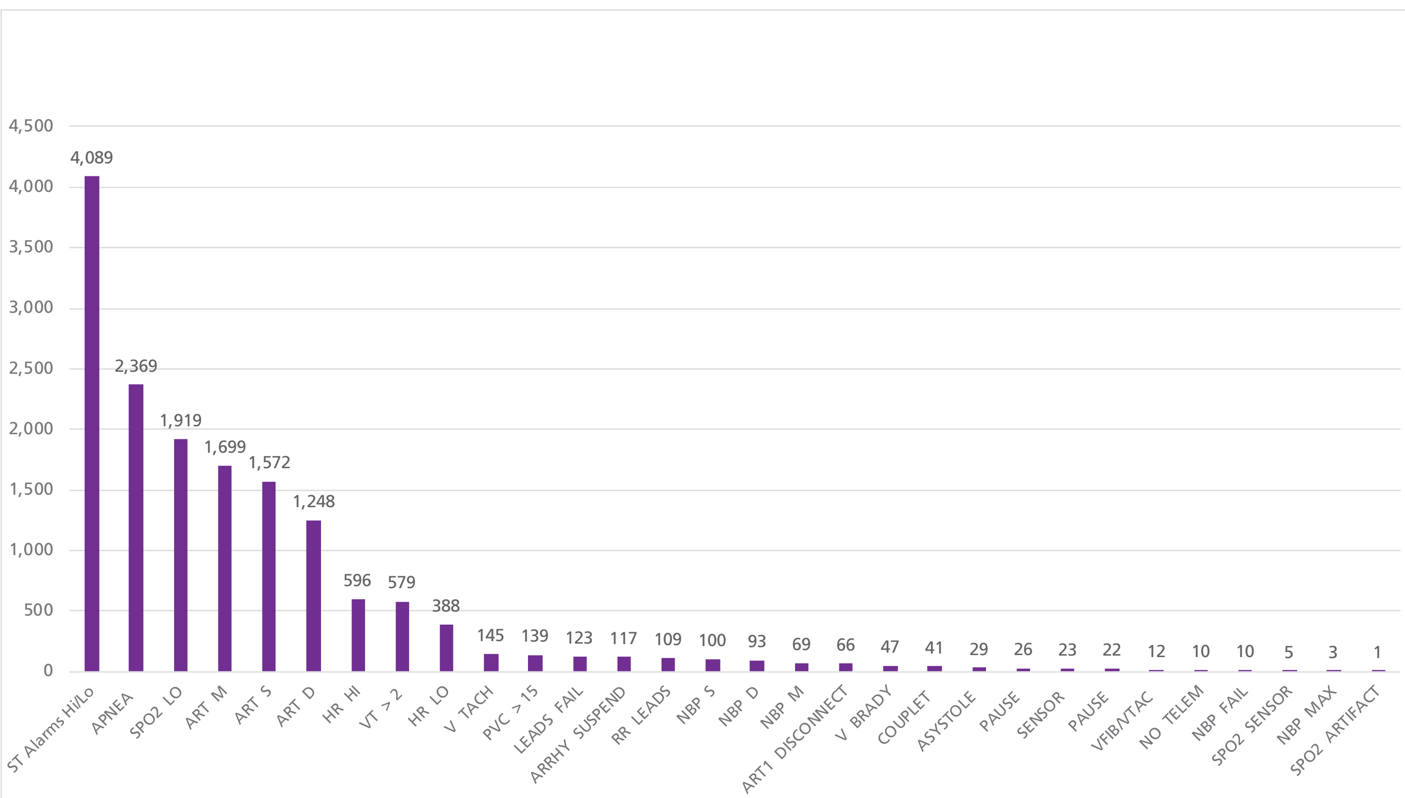

Figure 2. Number of cardiology care unit alarms according to type and trended for 1 week at a large large academic medical center

(Table 8). However, seven of the 45 patients (16%) had greater than 126 alarms/bed/day, while most patients fell well below 126 alarms/bed/day. Most importantly, 78% of the alarms were attributed to four of the 45 patients. Targeting interventions to those four patients would substantially reduce alarms on this unit.

Alarm data can be broken down further. For example, the large academic medical center demonstrated more precisely the alarm signals that were triggered by a single bed. The unit's daily alarm flood report (Table 9), which indicates those patients who have greater than 200% of the units average daily alarms, showed that one patient had 141 alarms/bed/day, representing more than seven times the unit's average of 20 alarms/bed/day. In this example, the predominant alarm limit breach was low HR caused by a patient whose baseline limit fell below the preset low HR limit. Customizing the low HR limit for this patient would have eliminated unnecessary alarm signals.

Lessons learned. Despite setting monitor alarm presets based on population, certain patients will still fall outside of these limits. For these patients, the alarms should be customized based on individual patient need. Biomedical engineers, information technology staff, and clinicians must consider the type of unit, available monitor features, and the facility's policies and procedures related to alarm limit orders and alarm customization when determining alarm default presets. Staff must be empowered to customize alarm limits, when appropriate, for patient outliers who are responsible for frequent alarm signals.

Part II: Recommendations to Reduce Alarms

Alarm Customization

Customization of vital sign alarm parameter limits based on patient need is one of the best ways to minimize false/nonactionable alarms.[2] As the data presented here demonstrate, the most common cause of unnecessary alarms are threshold breaches for HR, BP, respiratory rate (RR), and SpO_2. Manufacturers ship monitors with manufacturer-assigned default presets. These limits are generally set for high sensitivity, which may or may not be appropriate for the patient population to be monitored and may result in numerous nonactionable alarms. It is important to review these limits and determine whether adjusting manufacturer default presets prior to implementation on the care unit is necessary. A discussion among biomedical engineering, medical, and nursing leadership before implementation will ensure that the most appropriate unit-based preset limits are selected for the population being monitored. When assigning unit-determined preset limits, keep in mind that unnecessary alarms may occur if presets are not set to actionable limits. For instance, in one manufacturer's monitor, if the SpO_2 limits were set for a low of 90% and a high of 100%, then every time the patient's saturation reached 100%, an alarm occurred unnecessarily. In this example, the preset SpO_2 must be set higher than 100% to avoid unnecessary alarms for an SpO_2 of 100%.

Default presets (whether manufacturer, hospital, or unit based) automatically populate when a patient is discharged from the monitor and a new patient is admitted. Properly configured, unit-based default presets are generally appropriate for the majority of patients on a care unit. However, as described earlier, some patients will trigger numerous alarm signals because their baseline vital signs fall outside the preset limit. As a result, customizing alarms based on patient need is essential to reducing frequent and unnecessary alarm signals. The following examples illustrate how alarm customization can eliminate unnecessary alarm signals:

- A patient with baseline low perfusion who has a resting systolic BP below the unit default limit of 90 mmHg
- A patient with known hypertension whose systolic BP consistently exceeds the unit default limit of 180 mmHg
- A patient with slow atrial fibrillation with a resting HR that consistently falls below the unit preset HR limit of 50 bpm
- A patient with baseline respiratory compromise whose SpO_2 consistently falls below the unit preset limit of 90%
- A patient with baseline atrial fibrillation who consistently alarms for an irregular rhythm

Patient	No. of Alarms (%)
1	405 (56.33)
2	131 (18.22)
3	61 (8.48)
4	34 (4.73)
5	30 (4.17)
6	11 (1.53)
7	10 (1.39)
8	10 (1.39)
9	8 (1.11)
10	5 (0.70)
11	4 (0.56)
12	3 (0.42)
13	3 (0.42)
14	2 (0.28)
15	1 (0.14)
16	1 (0.14)
Total	719 (100)

Table 7. Number and percent of alarms for 1 day (in 2015) in an adult telemetry unit at a large health system. Calculated alarms/bed/day = 45.

Patient	No. of Alarms (%)
1	1,761 (30.84)
2	1,284 (22.48)
3	912 (15.97)
4	521 (9.12)
5	315 (5.52)
6	281 (4.92)
7	147 (2.57)
8	82 (1.44)
9	68 (1.19)
10	54 (0.95)
11	35 (0.61)
12	31 (0.54)
13	26 (0.46)
14	24 (0.42)
15	24 (0.42)
16	21 (0.37)
17	20 (0.35)
18	13 (0.23)
19	13 (0.23)
20	13 (0.23)
21	10 (0.18)
22	8 (0.14)
23	8 (0.14)
24	7 (0.12)
25	7 (0.12)
26	6 (0.11)
27	5 (0.09)
28	3 (0.05)
29	2 (0.04)
30	2 (0.04)
31	2 (0.04)
32	2 (0.04)
33	1 (0.02)
34	1 (0.02)
35	1 (0.02)
36	1 (0.02)
37	0
38	0
39	0
40	0
41	0
42	0
43	0
44	0
45	0
Total	5,711 (100)

Table 8. Number and percent of alarms measured for 1 day (in 2015) in a cardiac telemetry unit at a large health system. Calculated alarms/bed/day = 126.

If alarm customization does not occur in these instances, frequent and unnecessary alarms will occur continuously for nonactionable reasons. This leads to noise, distraction, and potential for alarm fatigue.

Lessons learned. Beyond unit-based settings, alarm customization based on the needs of specific patients eliminates noise and minimizes nuisance alarms, which can lead to alarm fatigue. Clinicians should be empowered to customize alarm limits based on the patient's baseline vital signs and within certain guidelines established through the institution's policies and procedures. Alarm customization is particularly important for patients who trigger the majority of alarm signals.

Use of Delays to Allow for Alarm Autocorrection

During patient care activity or with patient movement, preset alarm limits (regardless of whether the hospital is using manufacturer preset limits, unit-based preset limits, or patient-specific customized limits) often are breached, thereby causing an audible alarm. The care provider may view this as "noise" rather than a "signal" because the alarm occurs while bathing, suctioning, or positioning a patient.[3] Where possible, adding a short delay before an alarm is enunciated may be desirable.[4] For example, an ST alarm may signal a lack of oxygen to the heart. However, it is only problematic if it occurs for an extended period, such as greater than 1 minute. Alternatively, a patient's SpO_2 may decrease spontaneously during suctioning but quickly autocorrect when suctioning is complete. These are examples where a short delay may help to reduce nonactionable alarm signals from sounding.

Alarm Type	No.
Ventricular tachycardia	1
Leads fail	1
Asystole	1
Arrhythmia suspend	1
Pause	18
Low heart rate	119
Total alarms	141

Table 9. Medical telemetry unit daily alarm flood report from a large academic medical center. The data shown are the alarm signals triggered by a single bed after 12 hours of monitoring. Unit average alarms/bed/day = 20.

One way to eliminate unnecessary alarms is for the care provider to pause alarms during care activities; however, for various reasons, this does not always occur. Another way to eliminate unnecessary alarms is to determine whether the physiologic monitor allows a predetermined delay to be set for specific alarms. Numerous reports indicate the benefit of adding a short delay to SpO_2 and ST alarms to eliminate nuisance alarms.[3–7] These reports show that small changes, such as adding a 15-second delay to the SpO_2 alarm or a 1-minute delay to an ST alarm, could drastically reduce the quantity of nonactionable audible alarm signals.

Middleware is another method that allows unnecessary alarms to be filtered prior to sending the alarm signal to staff.[7] It serves as a "traffic cop," allowing specific alarms to be configured to a secondary device with a nominal delay. In doing so, middleware allows the primary system to autocorrect or be manually silenced. These extra few seconds provide the care provider with a confidence level that they are receiving mainly true alarms on their secondary alarm notification device. Adding delays through middleware, however, does not address the primary source of the alarm, which means the alarm will still occur at the bedside. In addition, secondary alarm notification devices should not be relied upon as primary means for alarm notification.

Lessons learned. The physiologic monitor should be assessed to determine whether programming of delays for SpO_2 and/or ST alarms is available to reduce unnecessary, nonactionable alarm signals. The use of middleware, which is a technology that allows filtering of alarm signals prior to sending them to the care provider's alarm notification device, should also be explored.

Patient Profiles

When it comes to default physiologic monitor alarm limits, one size does not fit all patients, especially in relation to patient populations with wide variations in age. Pediatric units often serve patients from infancy to adulthood. Some hospitals mix patients of various ages within a unit. A single set of default-preset limits for these circumstances becomes difficult to define. To avoid unnecessary alarming, the limits would have to be set so broadly as to not be useful. The use of patient profiles should be considered in these situations. Patient profiles are preset limits and are highly configurable. Profiles are helpful for defining alarm limits based on age range or disease conditions. The following examples highlight how patient profiles may be used to reduce frequent alarms:

- Terminal patients may cause excessive alarms for nonactionable reasons. Defining a "comfort-care-only" alarm profile may eliminate unnecessary alarms.
- Neonates younger than 36 weeks' gestation have a greater chance for retinopathy of prematurity caused by oxygen toxicity. Defining an alarm profile for neonates of less than 36 weeks' gestation may help identify when SpO_2 levels are too high.
- Pediatric patients have different vital sign ranges based on age.[8,9] Defining pediatric profiles to accommodate the difference in HR, BP, and RR, based on the patient's age (i.e., 0–12 months, 1–3 years, 4–7 years, 8–14 years, >14 years) could eliminate unnecessary alarms.
- ST monitoring is useful for patients with acute coronary syndrome to identify signs of oxygen deprivation to the heart but is not needed for all patients.[4] Use of an "acute coronary syndrome" alarm profile may help in identifying ST changes early in patients who would benefit from this technology.

Lessons learned. If the physiologic monitor allows the ability to define patient profiles, consider using this feature to eliminate unnecessary alarming for nonactionable reasons.

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Part III: Tips for Reducing Frequent Alarms

1. Avoid using manufacturers' default presets. Set monitor alarm default presets based on the population to be monitored.
2. When default alarm presets are too close to the patient's baseline vital signs, resulting in frequent or unnecessary alarms, customize alarms based on patient's needs. Consider a protocol to allow nurses to adjust alarm settings.[10]
   – For example: Protocol may allow staff to adjust monitor alarms by 10% above or below the unit's preset alarm limits without a physician order, or protocol may allow two nurses to review and approve a change in the patient's alarm settings without a physician order.
3. When a patient has frequent, nonactionable alarms, consider adjusting nonactionable alarms to a lower priority level (such as informational or, if permitted by hospital policy, to "off"). If unsure, discuss with senior nursing or physician staff or consult the hospital's policy.
   – Examples of alarms that may require a change in priority include atrial fibrillation alarms in a patient with chronic atrial fibrillation or ST alarms for patients with a pacemaker or bundle branch block.
4. When frequent alarms occur for specific groups of patients, determine whether the monitor has features that allow preset delays (e.g., SpO_2, ST). Brief delays could decrease the quantity of alarms by allowing the condition to autocorrect prior to breaching an alarm limit. Also consider defining profiles for groups of monitored patients.
   – Example: Pediatric patients (aged 0–18 years) have very different alarm thresholds for HR, BP, and RR. Use age profiles when admitting a patient to the monitor to optimize alarm thresholds around a patient's normal vital sign limits. Consider using profiles for other conditions, such as creating a comfort care or "do-not-resuscitate" patient profile to eliminate unnecessary alarms.

Summary

This article presented alarm data from three different hospital systems: a large health system of 36 hospitals, a small two-hospital health system, and a large academic medical center. Similar trends in data were found across these three settings. The data demonstrated that the number and type of alarm signals vary by care unit, regardless of the size of the system or facility. Alarm limit threshold breaches are responsible for the majority of alarm signals, and changing the manufacturer alarm presets to unit- or population-based alarm limit presets for vital signs (such as BP, HR, and SpO_2) will help reduce nonactionable alarms.

Hospitals are strongly encouraged to evaluate their alarm data to identify frequent sources of alarm signals. The data described here suggest that setting monitor default presets, based on evaluation of each unit's alarm data, is the first step of any alarm management plan. The data also support the assertion of National Coalition for Alarm Management Safety members: that the majority of alarm signals, regardless of unit, are initiated by a small number of patients. Therefore, customizing alarm limits for patients who consistently exceed the unit's alarm limit thresholds is an effective means of further reducing nuisance alarms.

Finally, this article offers strategies and tips for reducing nonactionable alarm signals. These techniques have proven highly successful in reducing the quantity of alarms at alarm coalition team members' hospitals and by the hospitals cited in the literature. ■

Acknowledgments

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Resources

- **AAMI Foundation.** Clinical Alarm Management Compendium. www.aami.org/alarmcompendium
- **American Association of Critical-Care Nurses.** AACN Alarm Management Resources. www.aacn.org/clinical-resources/clinical-toolkits/strategies-for-managing-alarm-fatigue?sc_camp=2DC6BA0C943B44E597A70E5E9400512B
- **National Association of Clinical Nurse Specialists.** Alarm Fatigue Toolkit. www.nacns.org/docs/NACNSFatigueToolkit.pdf
- **The Joint Commission.** 2016 Hospital National Patient Safety Goals. www.jointcommission.org/assets/1/6/2016_NPSG_HAP_ER.pdf
- **The Joint Commission.** Sentinel Event Alert Issue 50: Medical device alarm safety in hospitals. www.jointcommission.org/sea_issue_50
- **Health Technology Foundation.** Clinical Alarm Hazards and Management. http://thehtf.org/clinical.asp

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