Clinical Alarm Management & Reduction

Eliminating alarm proliferation in hospitals and health systems

Bernoulli®

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Introduction

Clinical alarms are supposed to alert caregivers that an intervention with a patient is required, or to remind them that care needs to be delivered. Unfortunately, patient-facing clinical staff are forced to respond to hundreds of daily alarms—the majority of which require no intervention—leading to alarm fatigue, disrupted clinical workflows, and compromised patient safety.

The issue has become so severe that the ECRI Institute identifies "the failure to recognize and respond to actionable clinical alarms… in a timely manner" as the second highest patient safety risk in its Top 10 Health Technology Hazards for 2016.[1]

Across the industry, response to this concern has grown, with organizations such as the Association for the Advancement of Medical Instrumentation actively leading the effort on alarm management safety. The American Association of Critical Care Nurses and the National Association of Clinical Nurse Specialists also offer resources materials to help organizations develop best practices.

Across the industry, response to this concern has grown, with organizations such as the Association for the Advancement of Medical Instrumentation actively leading the effort on alarm management safety.[2] The American Association of Critical Care Nurses and the National Association of Clinical Nurse Specialists also offer resources materials to help organizations develop best practices.

Most recently, in 2016, Phase II of the Joint Commission's National Patient Safety Goal (NPSG) on clinical alarm safety mandated the establishment of clinical alarm management policies and education as an institutional priority.[3] However, many stakeholders struggle to accurately define the current state of their alarm ecosystem, much less identify and implement potential solutions.

Scope of the Problem. Identifying the root causes of alarm proliferation, and standardizing approaches appropriate to specific patient populations, policies, and procedures, can be exceedingly difficult for even the most innovative organizations.

Where, for example, should hospital leadership target their focus? Reducing the total number of alarms? Reducing the average number of alarms per bed? Addressing the problem of "alarm flood," which is what happens when a caregiver is inundated with more alarms than they can physically respond to?

The sheer volume of technical and physiological alarm-equipped medical devices in many hospital units, in addition to other factors, such as lack of standards on the proper configuration of alarm parameters, inaccurate default settings, and narrow alarm limits contribute to the scope and complexity of the problem.

This white paper will outline the current state of clinical alarm management, demonstrate how to establish a baseline of a hospital's alarms, and outline innovative alarm reduction strategies to promote more efficient workflow, increase patient safety, and put hospitals on the path toward real-time patient monitoring and intervention.

Identifying an Alarm Management Team

Technology plays a critical role in clinical alarm management and reduction, but it is one piece of a larger solution. Achieving measurable progress in clinical alarm management requires that hospitals identify and support internal champions in all relevant departments, including nurses, respiratory therapists, biomedical engineers, and information technology staff.

These interdisciplinary experts must come together to assess the current state of the clinical alarm environment—by unit and facility—including establishing baseline alarm quantities by department, patient cohort, and time of day or night; reviewing current alarm settings; identifying and developing targets for reduction; implementing an agreed upon plan using a staged or phased approach; and evaluating appropriate interventions, policies, and standards. Without the input and expertise from hospital leadership, any clinical alarm management solution will fall short of institutional goals and may put full adoption at risk. Hospitals also need to develop a standard approach toward reducing the overall number of alarms sounding. To begin, the institution must establish a baseline alarm evaluation.

Baseline Study

How many alarms are sounding at your facility each day? Which units are most affected? How much of nurses or respiratory therapists' time is spent patient-facing versus responding to a steady cadence of alarms?

Before a hospital can begin to understand and develop an effective alarm management system, it must first understand its current environment. A baseline alarm study is a critical tool for conducting evaluations that include time trends, as well as in-depth alarm sensitivity and statistical and predictive analysis. This enables hospitals to standardize alarm management and to develop evidence-based best practices to safeguard patient safety, increase efficiency, improve patient and staff satisfaction, and identify critical areas for improvement. (See Fig. 1).

The study, typically conducted over a two-week to 30-day period, must include:

- Group analysis of alarm type by alarm category and frequency.
- Changes in type and frequency of alarm by unit.
- Evaluating effects of changes in alarm type and frequency by device.
- Alarm response behavior based on technical and physiological categories.
- Variation in alarm behavior by time, day, and day of week.
- Variation by room and by unit.
- Common limit violation alarm analysis.
- Specificity and sensitivity analysis to determine how potential changes in current limits may alter alarm volume.
- Statistical analysis of the distribution of measurements to identify standard deviations.

Technical Alarms:

Rank	Event Text	Alarm Count	Percentage of Total Alarms
1	SpO2 Non-Pulsat.	2931	35.09
2	Cannot Analyze ST	1215	14.55
3	Resp Leads Off	738	8.84
4	SpO2 Searching	708	8.48
5	Ecg leads off	650	7.78
6	SpO2 No Sensor	609	7.29
7	Cannot Analyze Ecg	460	5.51
8	IntelliVue in Standby	333	3.99
9	No Current IntelliVue Data	236	2.83
10	RA Lead Off	111	1.33
11	LL Lead Off	109	1.31
12	Ecg Noisy Signal	87	1.04
13	SpO2 Sensor off	69	.83
14	V Lead off	42	.5
15	LA Lead Off	29	.35
16	RL Lead Off	25	.3
Total		8352	

Physiological Alarms:

Rank	Event Text	Alarm Count	Percentage of Total Alarms
1	RR High	1819	22.71
2	SpO2 Low	948	11.84
3	RR Low	853	10.65
4	HR Low	727	9.08
5	CVPm High	434	5.42
6	ARTm Low	400	4.99
7	SpO2 DeSat	350	4.37
8	NBPm Low	348	4.34
9	HR Low	337	4.21
10	Apnea	245	3.06
11	NBPm High	204	2.55
12	PAPd High	183	2.28
13	ABps High	146	1.82
14	NBPs High	134	1.67
15	Extreme Tachy	131	1.64
16	ABps High	127	1.59
17	NBPs Low	106	1.32
18	Pulse Low	69	.86
19	Pulse High	61	.76
20	CVP Low	45	.56
21	ARTm High	42	.52
22	PAPd Low	42	.52
23	Asystole	42	.52
24	Brady(Pulse)	40	.5
25	ARTs Low	38	.47
26	ARTs High	30	.37
27	ABPm High	30	.37
28	RAPm High	26	.32
29	Extreme Brady	20	.25
30	Tachy (Pulse)	17	.21
31	ABPm Low	14	.17
32	UAPs Low	2	.02
Total		8010	

Fig. 1, right: Analysis of alarm type by category. Note that the top two technical alarms comprise <50% of total alarms in the category, and the top two physiological alarms comprise >30% of total alarms in the category.

Case in Point: The Hospital for Special Care

A baseline evaluation, followed by on-going analysis, enabled clinical leadership at The Hospital for Special Care (HSC) in New Britain, CT, to begin the process of classifying and mapping alarm trends.[4]

With information collected and by leveraging an end-to-end medical device integration and alarm management solution, HSC was able to evaluate thousands of alarms from more than 100 ventilators enabled the respiratory therapists and the alarm committee to start identifying nonactionable alarms that could be adjusted or eliminated entirely, which contributed to the 80% reduction in ventilator alarms. These changes greatly reduced the cacophony of alarms in the hospital; increasing both patient and staff satisfaction.

By changing practice based on evidence—staff was able to decrease non-actionable alarms by mitigating alarms caused by brief physiological changes that were self-correcting or did not carry clinically meaningful significance. By collecting high-resolution physiological data from their medical devices—not just the individual alarms—the interdisciplinary team was able to measure the potential impact on the number of alarms before making actual adjustments to their medical device settings.

Fig. 2 depicts an example of the potential impact of changing the lower and upper heart-rate alarm limits (bradycardia and tachycardia, respectively) and the resulting reduction in alarms on a given population of patients. This analysis is conducted by evaluating the actual measurements from the various patients to assess the impact post hoc using raw measurements. Hence, clinical staff can evaluate the efficacy of changing alarm limits in terms of the potential reduction versus the possible risk to patients.

Heart Rate Low Sensitivity Analysis

Low Limits	**59**	58	57	56	55	54	53	52	**51**
Alarm Counts	**1590**	1471	1325	1208	1114	1014	910	839	**777**
Percentage Change	--	-7%	-17%	-24%	-30%	-36	-43%	-47%	**-51%**

Heart Rate High Sensitivity Analysis

Low Limits	**124**	125	126	127	128	129	130	131	132	133	**134**
Alarm Counts	**1392**	1213	1130	1075	1008	935	884	830	785	738	**698**
Percentage Change	--	-13%	-19%	-23%	-28%	-33%	-37%	-40%	-44%	-47%	**-50%**

Fig. 2: Example of alarm reduction by adjusting default high and low heart-rate alarm limits based on the actual observed patient range and clinical practice; for both high and low heart rate, the first set of numbers on the right side of the table represent the default setting.

For example, HSC has the flexibility to determine which events will trigger alarms, as well as where and how clinicians will be notified. HSC's system provides its clinicians with high-fidelity, real-time, intelligent data pulled from myriad devices to improve patient monitoring and intervene before a patient's condition turns critical—offering unique point-of-care clinical decision support and enhancing patient outcomes.

Alarm Reduction—Evidence-Based Strategies

The problem with attenuating alarm data is achieving the balance between communicating the essential, patient-safety specific information that will provide proper notification to clinical staff while minimizing the excess, spurious and non-emergent events that are not indicative of a threat to patient safety. In the absence of contextual information, the option is usually to err on the side of excess because the risk of missing an alarm or notification carries with it the potential for high cost (e.g., patient harm or death).

For hospitals it's critical to analyze not only the alarms, but also actual, high-fidelity physiological data associated with them and that includes time trends, in-depth alarm sensitivity and statistical and predictive analysis.

Several techniques and strategies exist for reducing alarms, including trending alarms, which expand or contract patient alarm limits on individual devices; consecutive alarms, in which patterns of a consistent alarm detected, occurring over a clinician-defined period of time; and combination alarms, in which multiple parameters from different devices occurring simultaneously may together indicate a degraded patient condition. (See Figs. 3-6).

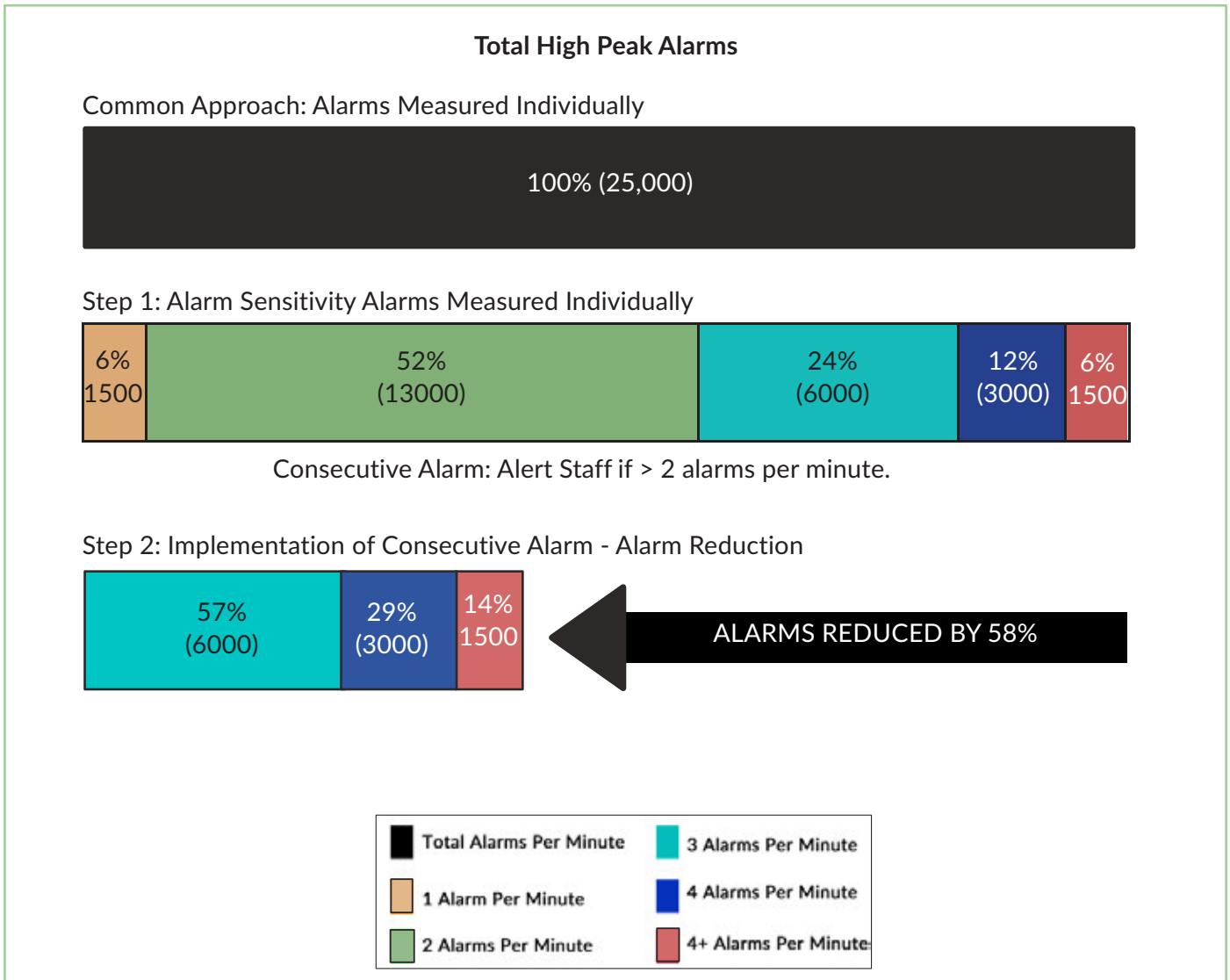

Fig. 3: An example of consecutive alarms, which looks at the occurrence and timing of alarms, not just individual alarms.

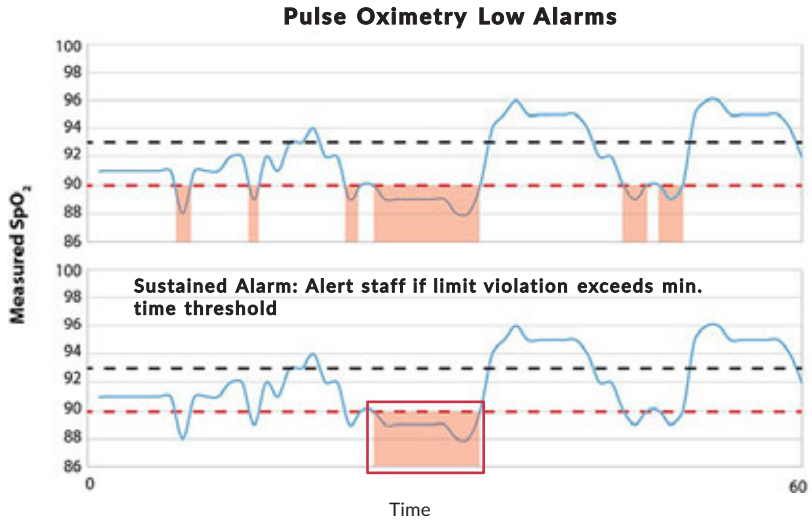

Fig. 4:
An example of sustained alarms, which requires setting a minimum time threshold that an alarm limit must be violated prior to sounding the alarm. Number of alarms reduced from 6 to 1.

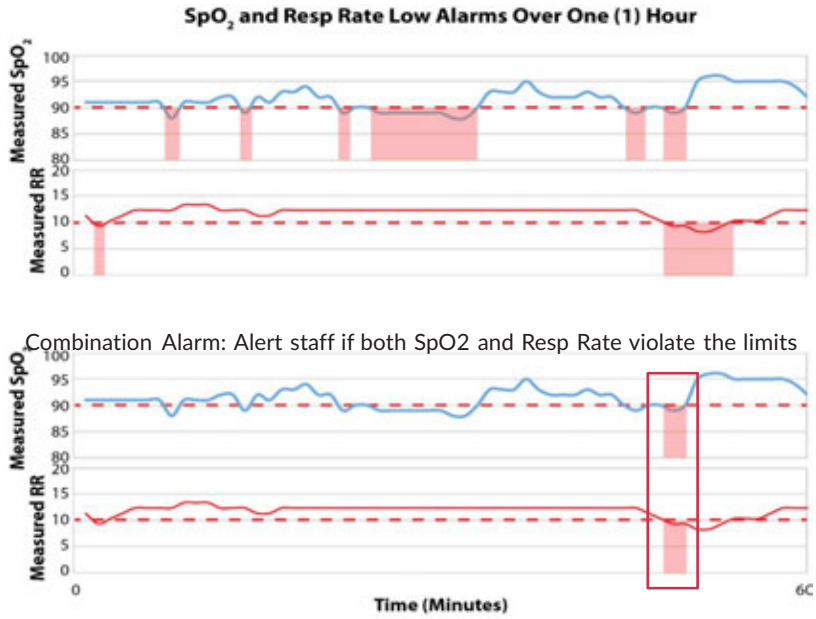

Fig. 5:
An example of combination alarms, which combines data from multiple alarms and/or non-alarming devices on the same patient. Number of alarms reduced from 8 individual alarms to one combination alarm.

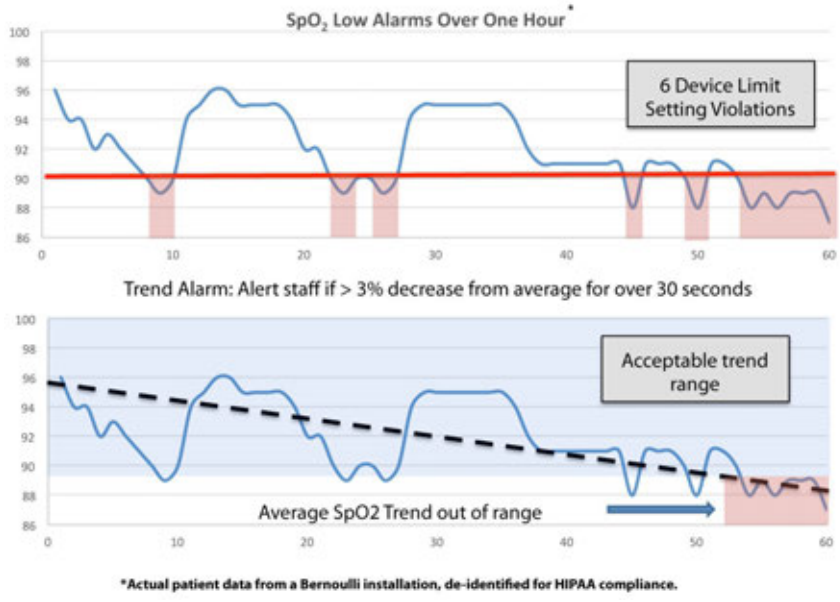

Fig. 6:
An example of trend alarms, which looks for trends in the patient's physiological data, not just alarms.

Case in Point: Virtua

Virtua is a multi-hospital healthcare system, headquartered in Marlton, NJ that specializes in cancer treatment cardiology, orthopedics, women's health, pediatrics, surgery, and neuroscience. The health system includes three hospitals, an ambulatory care center in Camden, and a range of other services, including health and wellness centers, rehabilitation, and long-term care centers, home care, physical therapy and mobile ICUs.

A recent study at Virtua looked at capnography as a sensitive and early predictor of opioid-induced respiratory depression in patients at risk for obstructive sleep apnea (OSA) during recovery from surgery and administered pain medications post-operatively for pain management (conscious sedation). In those patients who are at risk for or diagnosed with OSA, opioids can produce potentially life-threatening respiratory depression, especially in older, co-morbid patient populations.

The study measured pulse (HR), oxygen saturation (SpO2), respiratory rate (RR), and end-tidal carbon dioxide (ETCO2) continuously and compared alarms received through the bedside monitoring device with remote alerts designed to trigger only after a sustained delay and combinatorial alerts designed by the clinical team to indicate true respiratory depression. The goal was to reduce the total number of alarms without increasing risk to the patient.

Data collection and monitoring was performed continuously—from the time patients were placed on capnography until discharge. Data passed through a series of rules, which trended the values of HR, RR, SPO2 and ETCO2. When trends would individually exceed specific clinically-defined thresholds for a period of 30 seconds, a remote alert was transmitted to the nurse-call phone system. Nursing staff recorded patient condition and state, the alarm's validity, drug dosing, the patient general history and other contextual data.

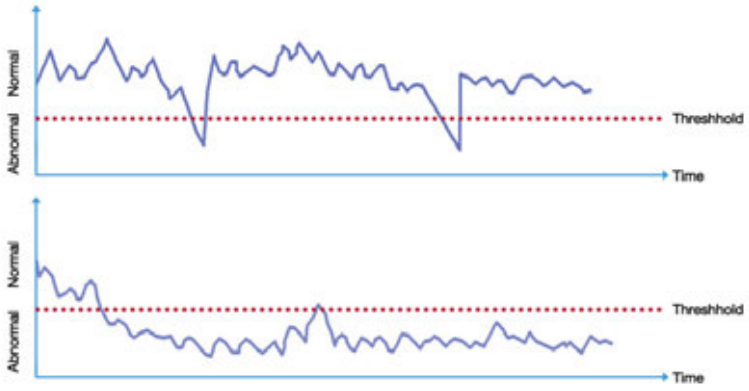

Fig. 7, left, illustrates instantaneous vs. trended alerts. Normally, these threshold breaches would trigger alarms. Rules were created to look for sustained notifications in which data trended or breached a clinically significant threshold and did not self-correct.

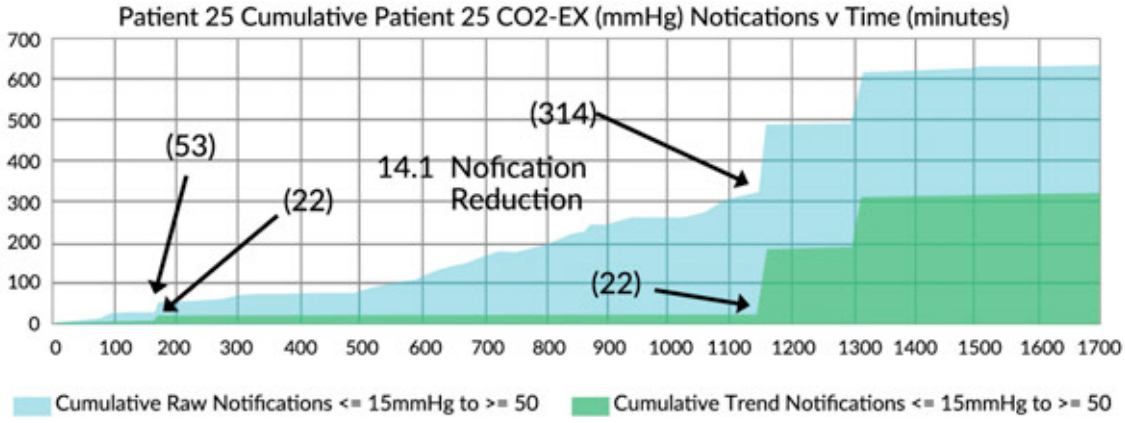

Fig. 8: Cumulative CO2-EX (mmHg) notification v time (minutes).

Across the patient population, the Capnostream monitors reported 75,000 individual notifications. Of these, the cumulative number of trended notifications was 55,000.

The study was able to demonstrate that by introducing a delay of 30 seconds prior to issuing an alert, patients at risk could be identified without inadvertently overlooking patients truly requiring clinical intervention. Using this approach, Virtua was able to achieve significant reductions in total alarms (in some cases, greater than 10:1) while at the same time causing no increased risk to the patient.

Conclusion

The two main purposes of alarms for medical devices is to alert caregivers about a possible unsafe situation for their patient or to remind them some type of care was required. With the flood of these types of products in the market, caretakers are now inundated with hearing and responding to hundreds of alarms from just one patient/resident's room each day. Multiply that by caring for multiple patients/residents, and that can equal thousands of different alarm sounds per day. This can result in clinicians becoming desensitized to the offending alarms and consequently ignoring them, known as alarm fatigue.

Addressing clinical alarm hazards in all their forms requires a holistic approach, free of the well-known departmental and data silos that hinder patient care and optimal clinical workflows. Technology certainly plays a critical role in alarm reduction and prioritization, but enterprise alarm management is a classic example of interdisciplinary leadership, involving clinical, IT, biomedical engineering, and other departments.

About Bernoulli

Based in Milford, CT, Bernoulli is a leader in real-time connected healthcare, with more than 1,200 installed, operational systems. Bernoulli *One*™, the company's flagship platform, is the market's only real-time, end-to-end, connected healthcare platform that combines comprehensive and vendor-agnostic medical device integration with powerful middleware, clinical surveillance, telemedicine/virtual ICU, advanced alarm management, predictive analytics and robust distribution capabilities into ONE solution. Bernoulli *One*™ empowers clinicians with tools to drive better outcomes, improve the patient experience, and enhance provider workflow. For more information about Bernoulli *One*™ or to view our case studies, visit www.BernoulliHealth.com.

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