Just a nuisance?

Abstract:

Background
Alarm management has become a topic of intense discussion, and has been identified as the #1 health technology hazard. Nevertheless, there are powerful reasons to emphasize sensitivity in alarming technology, and for most hospitals the alarm environment continues to become more intense.

Materials and methods
A comprehensive review of the published literature on alarm management strategies, alarm fatigue, and outcomes after false or non-actionable alarms was performed. Interviews with key opinion leaders in the field of nursing and alarm signal processing techniques were conducted, and 56 floor nurses in acute care units were surveyed with an anonymous web survey instrument.

Results
Literature review, site audits, web surveys and anecdotal reports all indicate that the absolute quantity of patient alarms is becoming problematic. Literature review also shows that a large proportion (40-80%) of alarms are not actionable – i.e., that they are 'false' from the perspective of providing a valuable summary of information to a clinician.

Review of literature and survey of nurses indicates that an environment of intense alarm frequency and volume can result in serious negative outcomes. Consequences include: missing true positive alarms; breach of monitoring protocols; stress to patients, families and caregivers and poor use of nursing time. Hundreds of avoidable deaths through alarm fatigue have been reported, while 10% or more of nursing time is spent in responding to non-actionable alarms.

Conclusions
Non-actionable alerts account for the majority of alarms. High levels of non-actionable alarms contribute to stress for staff and patients, absorb a significant amount of nurse time, and may have important negative clinical consequences. Action can be taken to reduce non-actionable alarms and consequences, which must begin with measurable data to drive an informed solution.

Context of study:
Alarms for technical faults or patient physiological parameters have been built into a wide array of medical equipment. As equipment proliferates in the hospital, the frequency and volume of alarms is becoming problematic. With highly sensitive alarm settings, many alarms may not be clinically relevant.

Study purpose:
Review the evidence that current alarm environments are problematic, define 'excessive alarms' and investigate the consequences of excessive alarming.

Key takeaways:
Current alarm settings lead to an environment with excessive false positives in terms of clinical relevance. At a minimum, these less relevant alarms lead to increased costs and stress for patients and nurses – at a maximum they result in truly actionable alarms being missed. If actionable alarms are missed among too many non-actionable alarms, patient safety is jeopardized.

PHILIPS

Background: A cause for alarm?

A focus of debate

'Alarm Management' has become a hot topic in discussions about care quality. It has attracted the attention of many key healthcare industry bodies: **ECRI named 'alarm hazards' as the number 1 health technology hazards in both 2012 and 2013** while The Joint Commission has recently published new requirements that will come into force (see below). Outside of the healthcare sector, the wider public is becoming aware of terms such as 'alarm fatigue' through high-profile cases, and through their own experience of the hospital environment.

According to the ECRI Institute, **216 reports of alarm-related deaths were filed with the FDA between 2005 and 2010**. In Pennsylvania alone, **35 deaths** related to physiologic monitor alarms have been reported since 2004, and at least **9 (25%) were directly attributed to alarm fatigue** (https://www.ecri.org/Forms/Pages/Alarm_Safety_Resource.aspx). Alarm related deaths occur when clinician attention is not redirected to an urgent, care-needed situation. This may be because alarm settings are inappropriate, because alarms have been silenced, because alarms are not distinct enough to capture clinician attention, or because equipment fails to generate a needed alarm.

The Joint Commission Takes Action

In response to an increasingly unsustainable environment, The Joint Commission has issued NPSG.06.01.01 as a National Patient Safety Goal to "Improve the safety of clinical alarm systems." NPSG.06.01.01 will become effective on January 1st 2014, and includes performance requirements that will need to be met in the calendar year of 2014 (see Figure 1). Further performance requirements will need to be met by 2016. Hospitals are now faced with an unambiguous mandate to address the performance of alarm systems, with direct accreditation and financial consequences for failing to meet performance requirements. Most immediately, hospitals need to understand their own alarm environment, and identify if it is problematic – and if so, what is the nature of the problem.

Elements of Performance for NPSG.06.01.01

A 1. As of July 1, 2014, leaders establish alarm system safety as a [critical access] hospital priority. **R**

A 2. During 2014, identify the most important alarm signals to manage based on the following: **R**

- Input from the medical staff and clinical departments
- Risk to patients if the alarm signal is not attended to or if it malfunctions
- Whether specific alarm signals are needed or unnecessarily contribute to alarm noise and alarm fatigue
- Potential for patient harm based on internal incident history
- Published best practices and guidelines

Figure 1: Joint Commission Requirements for 2014

Background: An environment of constant noise

How many alarms?

In her paper "Monitor Alarm Fatigue: An Integrative Review", Maria Cvach estimates that staff, patients, and families on medical units may be exposed to up to **700 alarms per day**. In its pilot program study for Medical Progressive Care and Cardiology Care Units, the Association for the Advancement of Medical Instrumentation (AAMI) estimated **183 alarms per bed per day**.

A recent Philips audit showed that nurses may be exposed to up to **3.7 alarms per minute** (Figure 2). If each alert takes time to address, the demand on nursing time can become prohibitive. Time spent on responding to alarms is not spent on pro-active patient care, with possible impact on quality and patient satisfaction. In a web survey of acute care nurses conducted by Junicon, more than 20% of ICU nurses believed that they received **>100 alarms per hour** (Figure 3).

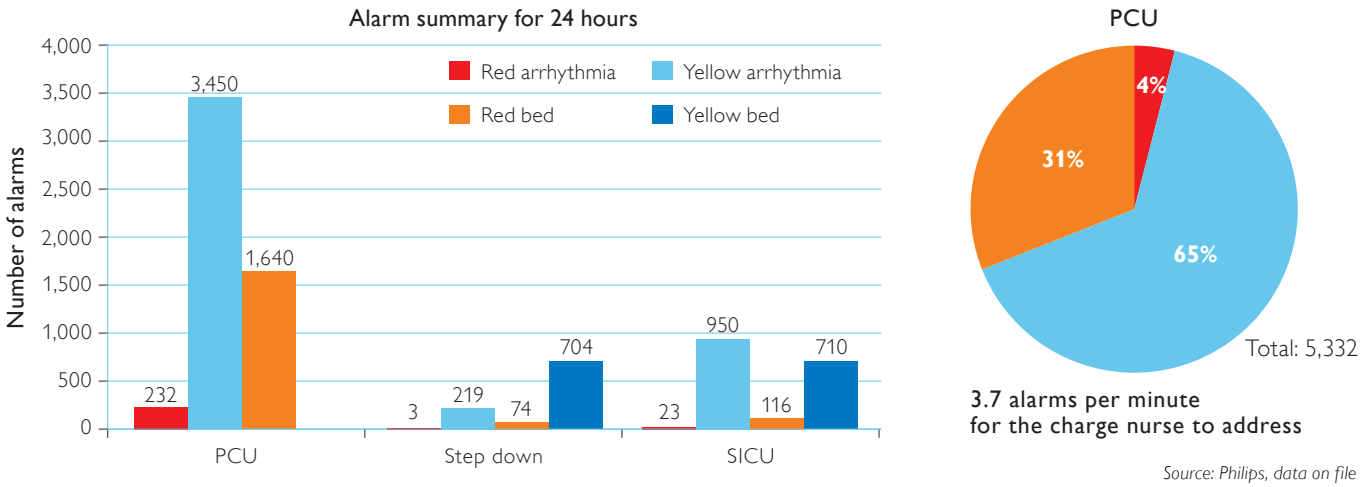


Figure 2: Alarm frequency in one hospital audited by Philips Healthcare.

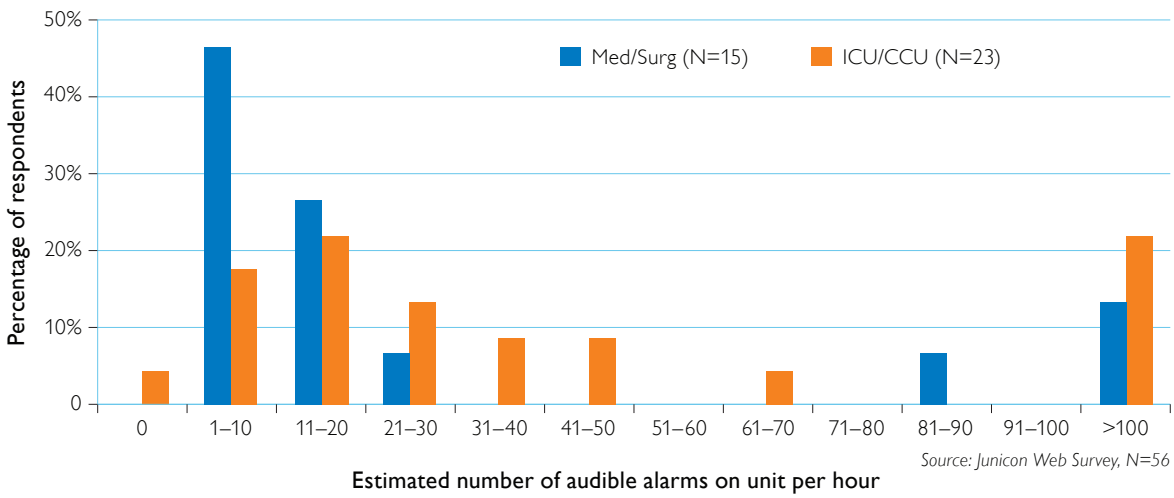


Figure 3: Self-estimated frequency of alarms by department.

Background: Alarms are a necessary part of patient care

Supply and Demand for Attention

The primary goal of patient care in the hospital setting is to optimize patient outcomes. This requires clinicians to take specific actions, based on the information they have about each patient, and based on their clinical knowledge, judgment, and familiarity with evidence-based protocols. In almost every setting, there are more patients than clinicians, so it is a challenge to simultaneously observe all patients at all times. Furthermore, the amount of potentially relevant information about each patient is very large – although at any given moment, not every measurement will have clinical relevance. The 'demand' for clinician attention is enormous. As a result, clinicians are required to filter information so that a finite 'supply' of attention is directed to the most valuable patient information.

Information Filtration

A simple filter is to use an alarm setting. Alarm settings are basic decision rules: IF a decision rule is violated (i.e., a physiological parameter is outside of 'normal' range), THEN generate a notification to capture the attention of one or more clinicians. Alarms allow the clinical team to step away from continuously observing each patient's information and focus on other tasks, secure in the knowledge that an alarm will draw their attention to information that is of critical importance.

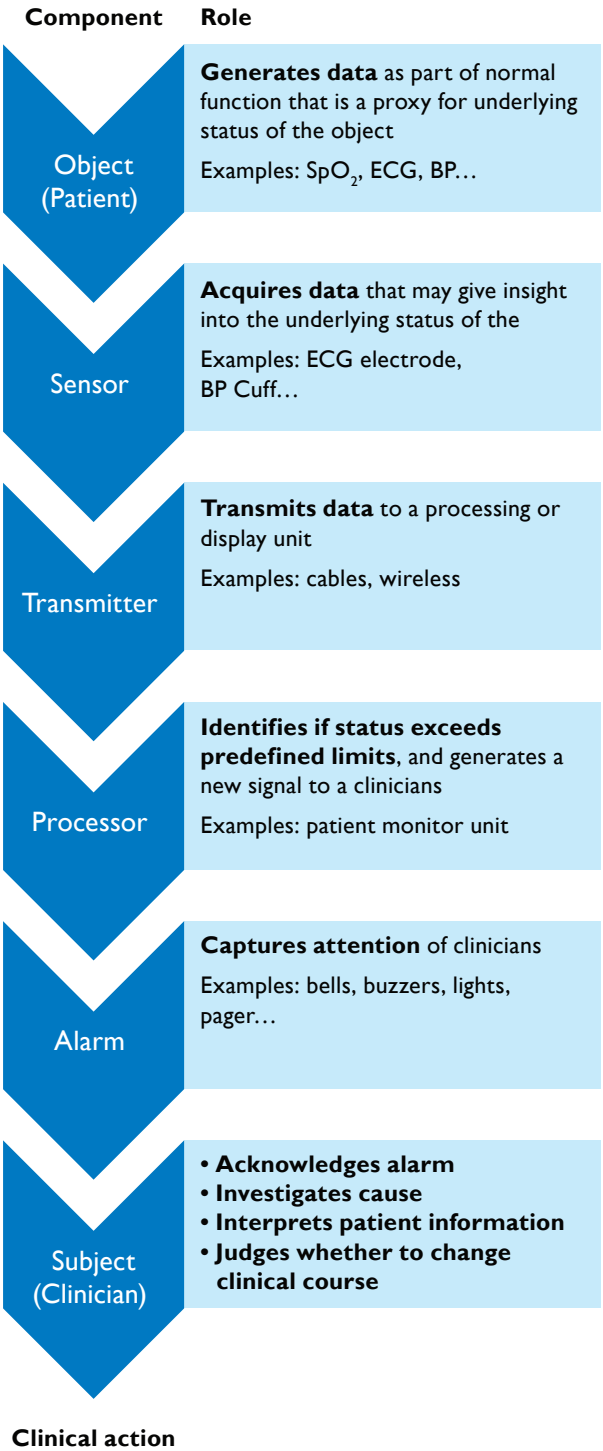


Figure 4: Simplified schematic of the components of an 'Alarm'

But alarms are no longer good information filters

Alarms are a human system

For as long as closed-loop adjustment of therapeutics remain challenging from a clinical, ethical and regulatory perspective, patient monitoring will always depend on the subject, i.e., the clinician. An alarm system is first and foremost a **human system**, and serves solely to help and support the activities of a clinician.

If one accepts that the purpose of an alarm is to act as a filter to draw clinician attention to the most important clinical information in a mass of data, then it is necessary to assess how well an alarm system performs in these terms.

Sensitive to the consequences

To understand how a situation of almost continuous alarming has developed, we need to examine the concepts of sensitivity and specificity with regard to alarm settings. The consequences of a false negative result (patient needs urgent clinical attention, but no clinician is alerted) are far more immediately harmful than a false positive result (patient does not need clinical attention, but a clinician is alerted). Therefore, alarm settings for each device emphasize sensitivity over specificity, and allow for a large number of false positives in order to prevent any false negatives.

Regulatory requirements push manufacturers to set default settings to high levels of sensitivity, and fear of liability for adverse events can dissuade clinicians from changing default settings. The result is that alarm settings for each device are highly sensitive – and the focus on sensitivity over specificity is perfectly rational for each device.

A broken filter

The catch is that highly sensitive settings that make sense for each individual device are starting to become unproductive when replicated across many devices.

As the number of medical devices have proliferated, and the number of parameters that can be monitored for each patient have increased, the number of 'things that can go beep' has increased also. With a strong bias towards sensitivity, the net result is that there are often unsustainable numbers of alarms competing for clinician attention. Continuous demand for attention is counter-productive when many alerts are 'false positives'.
In effect, the role of the alarm as an effective filter of 'what is important' is failing, and clinicians are once again frequently faced with too much demand for their attention.

> "We in healthcare have created the perfect storm with all of these monitoring devices…In hospitals today, we have too many alarming devices. The alarm default settings are not set to actionable levels, and the alarm limits are set too tight. Monitor alarm systems are very sensitive and unlikely to miss a true event; however, this results in too many false positives. We have moved to large clinical units with unclear alarm system accountability; private rooms with doors closed that make it hard to hear alarm signals; and duplicate alarm conditions which desensitize staff."
>
> *Maria Cvach, RN, Director of Nursing and Clinical Standards at Johns Hopkins*
>
> *Copied with the permission of the AAMI Foundation and the Healthcare Technology Safety Institute*

True or false: All alarms are either right or wrong?

In many respects, the language of 'True 'and 'False' is misleading when thinking about the effectiveness of an alarm system. Because the alarm system is dependent on alerting a subjective human (the clinician) to possible changes in a complex object (the patient), the relevance of any alarm is heavily dependent on context. While there are some values that are **always** indicative of a problem, in many cases, the clinical relevance of an alert depends on other information about the patient. There are some alarms that are genuinely the result of a false signal. However, many alarms are 'false positives' not because the alarm is technically incorrect, but because the context means that the alert is not clinically relevant. It is helpful to think about alarms not as binary 'True or False', but in terms of how well they function as a tool to focus clinician attention on important information. The terms 'non-actionable alarms' or 'nuisance alarms' may be more useful.

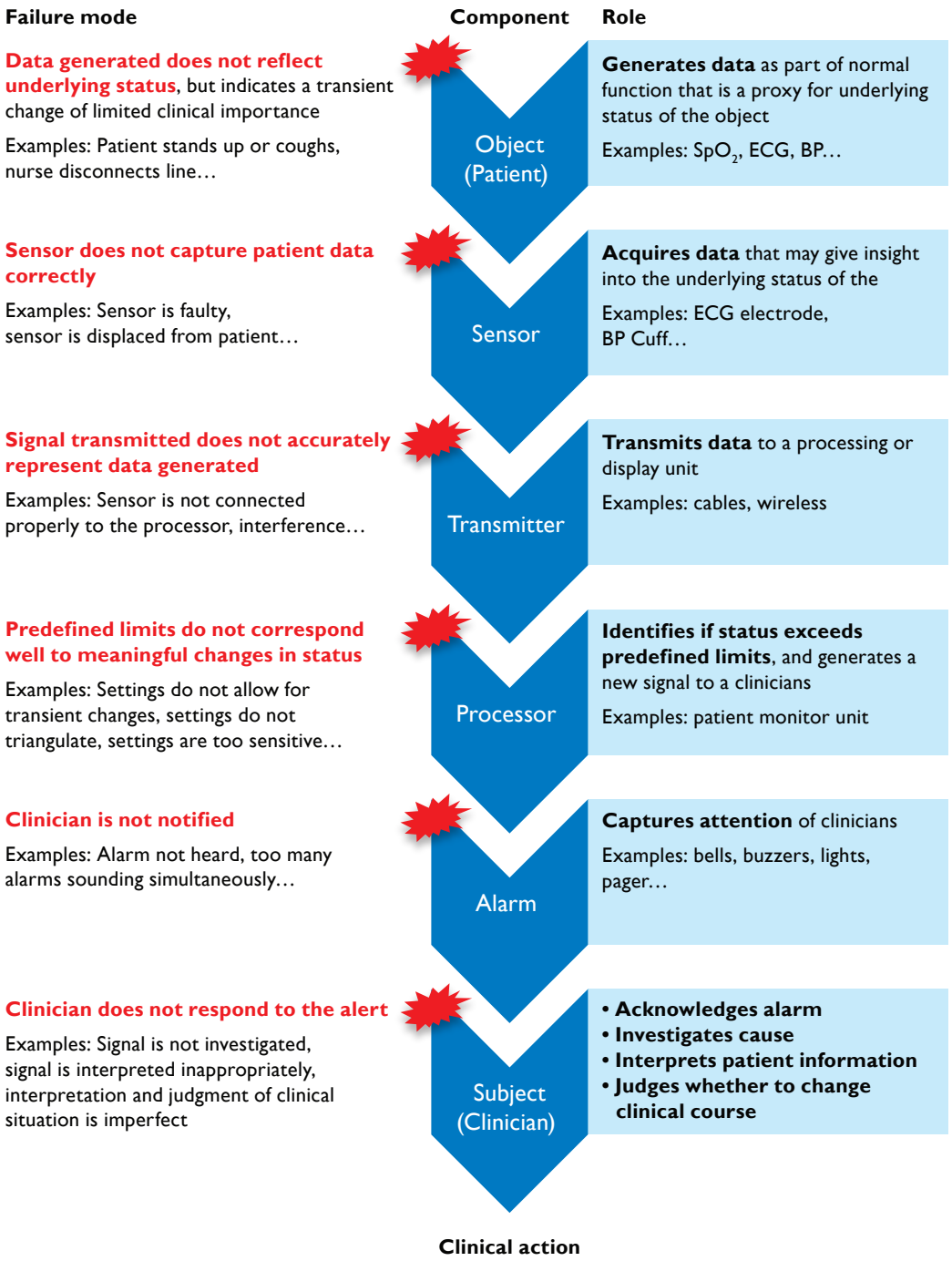


Figure 5: Possible failure points in the alarm pathway

How much is too much?

Crying out loud

Hospital systems rely on devices to alert healthcare workers of potential changes in patient status and medication needs, requests for attention from patients, and equipment upkeep. The amount of noise in hospitals has been steadily rising for the last 30 years. This onslaught of sounds and alerts has had negative impacts on patients, their families and hospital staff. In addition, hospital systems have experienced financial impacts from associated litigation.

Furthermore, to compete with other alarms and background noise, many hospital units increase the volume on monitor units so they can be heard. This can be self-defeating: the decibel level on many units is loud enough to drown out any new alert, potentially leading to missed or delayed reaction to an actionable situation.

Crying wolf

Whether or not alarms are technically false, there are undoubtedly a large number of alarm events that do not correspond to a truly urgent clinical situation. This may result from any of the causes identified on the previous page, and potentially from multiple factors together. The net result is that there are too many alarms for non-actionable situations.

Clinical studies have sought to define and quantify the frequency of clinically relevant alarms among the total . Anecdotally, every clinician in a modern hospital today will indicate that ‘nuisance alarms’ are a daily occurrence and a fundamental part of delivering care today.

The alarm management challenge

The essence of the alarm management challenge is this combination of issues: the absolute number of alarms is becoming problematic, and too few of those alarms are truly justified as an interruption of clinician activity – whether due to false alarms or to true alarms that are not clinically relevant.

Logically, simply having alarms signaling on these units is not problematic in and of itself. The risk of missing an actionable, relevant alarm is enough to warrant devising strategies to improve the performance of the signal pathway in alerting clinicians to meaningful changes in patient status. That is to say, turning off the monitors is not an option. Patient monitoring alarms are indispensable at this point, especially on units that have a high patient to nurse ratio.

Alarm management is not synonymous with false alarm elimination, though improving the diagnostic yield of alarm systems is undoubtedly a key part of the puzzle. The real challenge is to make alarms consistently useful in supporting the clinical team in delivering excellent care to their patients. Meeting this challenge may have technical and human components, and can rely on technological, operational, organizational and cultural changes.

Evidence that alarms are excessive

Alarms are frequent, and frequently irrelevant

Today most existing alarms are threshold alarms that sound when set limits are breached. These alarms tend to have high sensitivity and low specificity and are often redundant, resulting in high alarm loads. Signal rates differ by hospital unit, as well. **Chambrin et al, 1999** found that in 1,971 hours of observation in an ICU unit there were a total of 3,166 alarm signals. That is one alarm sound every 37 minutes. By contrast, **Schmid et al, 2011** found that in 124 hours of observation there were a total of 8,975 alarm signals overall in a general care unit. That is roughly 1 alarm every 50 seconds.

Studies have shown that non-actionable alarm signals can be as high as 80% and average about 50% of total alarm signals **(Aboukhalil et al, 2008)**. Conversely, true actionable alarm sounds are low. **Seibig et al, 2010** reported that only 17% of alarm signals required intervention.

Non-actionable alarm signals are often caused by motion artifacts, healthcare professional manipulation of the patient or patient movement, inappropriate alarm limits, or faulty technology.

Alarms have also proven to be unreliable. **Blum et al, 2009** reported that alarms have only 75% specificity. **Gross et al, 2011** found that only 34% of clinical alarm signals were true actionable alarms. **Hu et al, 2012** found that in the ICU only 15% of alarm signals were clinically relevant, while in the ER 0.7% of alarm signals are clinically relevant.

Study	Overall alarm signals measured	False alarm signals (%)
Schmid et al, 2011	8,975	80
Aboukhalil et al, 2008	5,386	42.7
Blum et al, 2009	1,012	32
Borowski et al, 2011	9,290	43

Table 1: Alarm signal rates.

The consequences of excess alarms: Stress

Alarm noise can increase stress to patients and healthcare professionals

Constantly sounding alarms contribute to the environmental (background) noise in a hospital. Those environmental sounds can reach more than 80dB, clearly in excess of the WHO recommendation of 30-35dB of environmental noise **(Aboukhalil et al, 2008)**. A survey conducted by **Stephens et al, 1995** found 79% of responding healthcare professionals, patients, and visitors thought noise levels to be a problem in the ICU. Noise levels at the patient's head, surrounded by alarm systems, was found to be 60-80dBA in this study. Noise can create acute stress for patients and chronic stress for clinicians, with direct physiological and psychological consequences (Figure 6.)

High noise levels negatively affect patient outcomes, as evidenced by a sleep study which linked noise in an ICU to altered heart rate and blood flow (**Cropp et al, 1994**). **Aboukhalil et al, 2008** stated that noise interrupts patient sleep leading to sleep deprivation and a depressed immune system. These disruptions have an effect on recovery and length of stay. Lower noise levels have been positively correlated to lower re-hospitalization rates and shorter stays in ICU patients (**Aboukhalil et al, 2008**) and in surgical patients (**Cropp, 1994**). **Solet et al, 2012** also found that reductions in noise in ICUs had positive effects on patient outcomes. Patients had better oxygen saturation, blood pressure, heart rate and overall satisfaction.

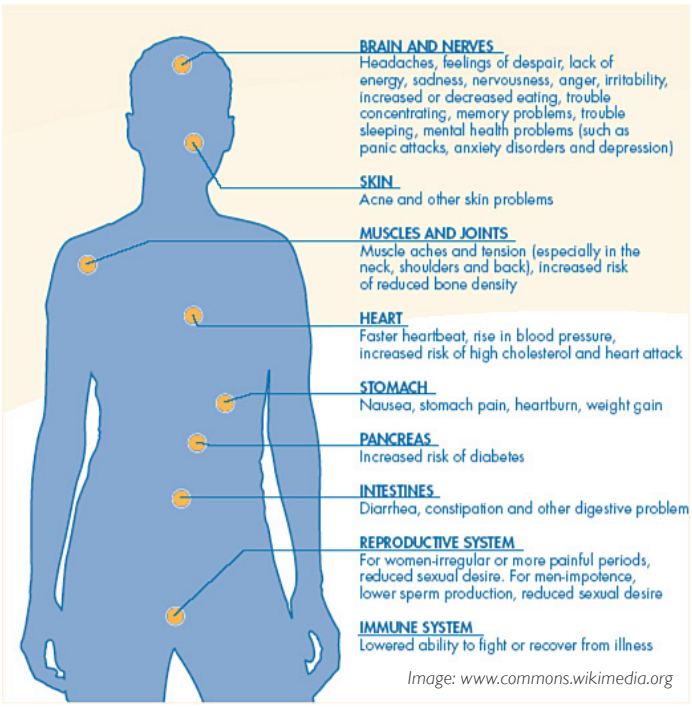


Figure 6: Effects of stress on the body.

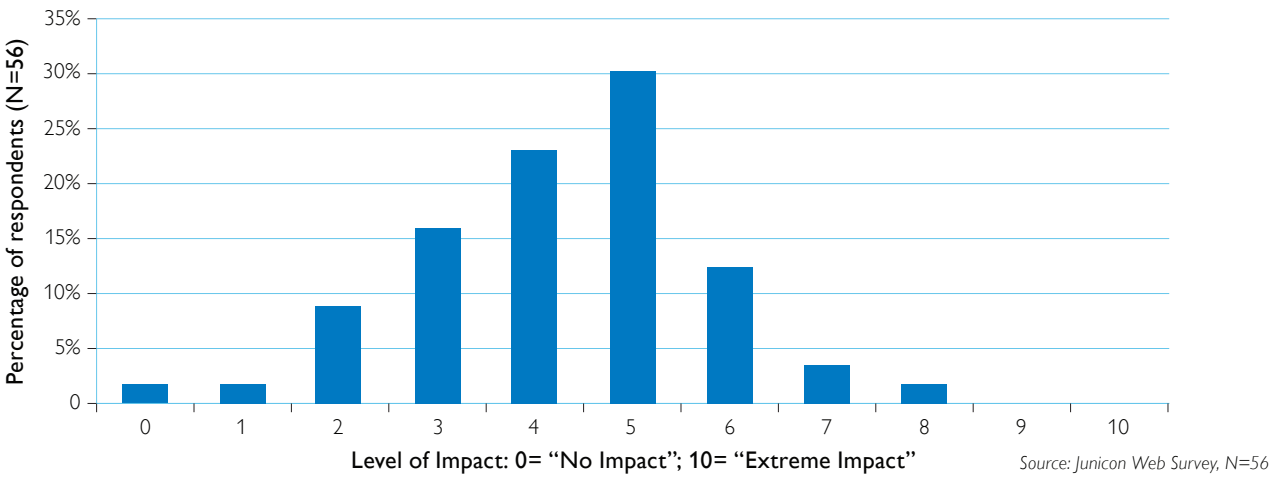


Figure 7: Impact of alarms on psychological well-being of nurses.

The consequences of excess alarms: 'Alarm fatigue'

Driven to distraction

With the proliferation of alarms and alerts in care settings, hospitals are facing a new challenge: a syndrome called alarm fatigue.

The 2011 Summit on Clinical Alarms convened by the AAMI, FDA, TJC, ACCE, and the ECRI Institute addressed concerns related to nuisance alarms. Mary Logan, AAMI President, and Scott Colburn, Lieutenant Commander of the US Public Health Service, defined alarm fatigue with a clear call to action:

High alarm loads and non-actionable alarm signal rates can cause stress and lower productivity

One of the most problematic issues of high alarm load is alarm fatigue, which was rated the number one technological hazard in 2012 according to **Cvach et al, 2012**. Alarm fatigue is caused by high overall number of alarm signals and high rates of non-actionable alarm signals.

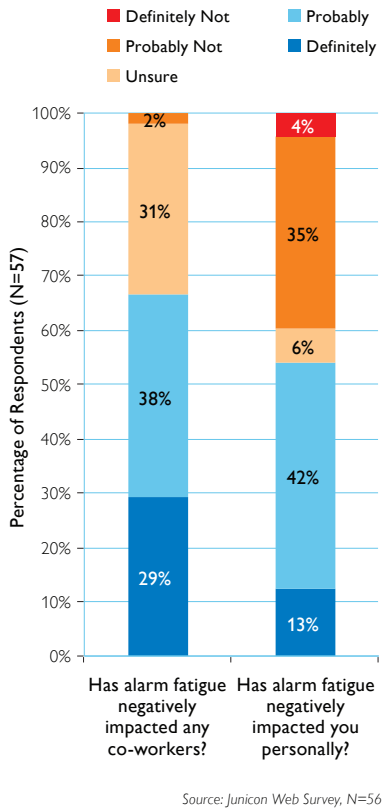
In a study by **Varpio et al, 2012** nurses in a neonatal ICU expressed feelings of being overwhelmed by the number of alarm signals sounding. They commented that alarms are too sensitive.

- Alarm fatigue is when a nurse or other caregiver is overwhelmed with 350 alarm conditions per patient per day.
- Alarm fatigue is when a patient can't rest with the multitude of alarm signals going off in the room.
- Alarm fatigue is when a true life-threatening event is lost in a cacophony of noise because of the multitude of devices with competing alarm signals, all trying to capture someone's attention, without clarity around what that someone is supposed to do.
- Alarm fatigue is compounded by inconsistent alarm system functions (alerting, providing information, suggesting action, directing action, or taking action) or inconsistent alarm system characteristics (information provided, integration, degree of processing, prioritization).
- Alarm fatigue is a systems failure that results from technology driving processes rather than processes driving technology.

Excerpted from: http://www.aami.org/htsi/alarms/pdfs/2011_Alarms_Summit_publication.pdf.

"Clinicians take inappropriate actions from nuisance alarms, such as lowering the alarm volume, extending alarm limits outside a reasonable range, or disabling alarms."

Frank Block, M.D.,
Co-Chair of AAMI's Alarms Committee.



Source: Junicon Web Survey, N=56

Figure 8: Self-reported incidence of alarm fatigue.

In Junicon's Web Survey, 55% of nurses indicated that they had probably or definitely been impacted by alarm fatigue.

Importantly, alarm fatigue from signal overload is a danger to the patient

An emergency situation overlooked due to alarm fatigue has the potential to threaten the patient's life. **Korniewicz et al, 2008** reported on a JCAHO review of 23 patient deaths or injury related to mechanical ventilation. 68% of those were alarm related. **Solet et al, 2012** reported that from 2005 to 2008 between 200-566 patient deaths were attributed to alarm fatigue.

Alarm signals can contribute substantially to environmental noise, to the degree that nurses in critical care units have reported headaches and burnout (**Cropp et al, 1994**). **Solet et al, 2012** reported irritability and mental fatigue in healthcare professionals. Another study had similar results where healthcare professionals had difficulties hearing each other, had impaired vigilance or were distracted, resulting in altered moods and impaired performance (**Solet et al, 2012**).

Stressed healthcare professionals may have impaired decision making abilities, especially during critical situations. An unintended consequence to over-alarming is alarm desensitization. This is a phenomenon that can clearly have real-world consequences. The ability to hear alarms as they occur impacts the ability to respond to the alarms. An increase in false positives and nuisance alarms leads to an increase in false negatives (through non-response to actionable alarms).

The consequences of excess alarms: Unconscious desensitization

Humans filter when technology doesn't

Remembering that an alarm system is fundamentally a **human system**, it is reasonable to expect that humans will play a critical role in the overall function and performance of the system. If an alarm has been found to be 'false' (i.e., non-actionable), the urgency to respond to subsequent signals may diminish. In some cases this may lead to not hearing the next alarm at all, despite the alarm signaling.

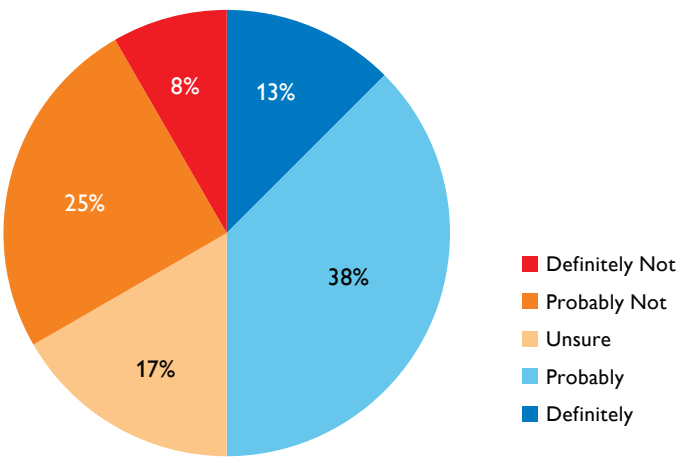
Consciously or unconsciously, the subject of an alarm (i.e., the clinician) will inevitably begin to compensate for excessive frequency of alarms and low yields in terms of clinical relevance. The result is a second layer of filtration, that is subject to human idiosyncratic errors. If alarm settings prioritize sensitivity over specificity, they may become self defeating if they prompt clinicians to 're-filter' the alarm signals in a way that prioritizes specificity over sensitivity. 50% of nurses admitted that they felt excessive alarms diminishes their sensitivity to true alarms (Figure 9).

Desensitization = decreased sensitivity = increased specificity

The end result of desensitization may thus be a paradoxical loss of true positive reactions to true positive clinical issues. This may seem counter-intuitive to clinicians who have learned how diagnostic yield is described by the Receiver-Operator-Characteristics (ROC) curve, and how for any test, it is possible to increase sensitivity at the expense of specificity, or vice versa. The explanation stems from the multi-stage nature of the alarm system, and the compensating role that humans play in interpreting signals. In this model, an increase in false positives can paradoxically result in an increase in false negatives in terms of clinician response.

The impact of human response to excessive false positives may not be conscious, or even controllable. Some of the adaptations to an environment rich in false positives may be biological as much as psychological, and completely beyond control. In the case of the NICU nurse quoted above, it is not 'her fault' that she is no longer able to hear alarms to the same degree. The entire system has become dysfunctional.

> "That's really frustrating because most of the time they're [patients are] just playing or something, and we can't turn them [the monitor] off. But then we have to hear the dinging continuously. And I think you kind of turn off your ear. You might not respond as quickly as you would if that [monitor] wasn't always on."
>
> *NICU nurse (Varpio et al, 2012)*



Do you feel like alarm fatigue due specifically to false alarms has negatively impacted your ability to hear or see actionable patient alarms?

Source: Junicon Web Survey, N=56

Figure 9: Alarm fatigue can lead to desensitization.

The consequences of excess alarms: Conscious desensitization

High alarm signal rates can lead to healthcare workers breaking protocol

High rates of non-actionable alarms cause health care professionals to be distrustful of the alarm signals they hear. This results in breaking protocol by ignoring the alarm signals, turning off alarms, or delaying response time. **Bliss et al, 2000** found that undergraduate students undergoing a primary task and responding to an alarm signal tended to match their response rate to the reliability of the alarm. A study in a medical/surgical setting by **Gross et al, 2011** showed that 41% of alarm signals were ignored and 36% were classified as no response (it took longer than 5 minutes or the alarm was silenced).

In several high profile cases, serious adverse events or deaths have occurred after clinicians silenced 'nuisance' alarms, and thereby missed critical true positive events. Such cases can lead to huge liability for the hospital, intense negative PR and major morale issues among staff.

Clinicians will often prioritize workflow over unreliable alarms

Workflow interruptions from high alarm loads can result in missed tasks and reduced productivity. **Bitan et al, 2004** pointed out this problem among the nursing staff: "An excessive amount of information from alarms can possibly interfere with nurses ability to schedule their tasks efficiently." A study by **Bliss et al, 2000** found that simultaneously the typical workload and alarm load can reduce performance, especially when responding to an alarm signal. In a study by **Varpio et al, 2012**, 70% of nurses indicated that they would choose to not respond to alarm signals in order to not interrupt workflow.

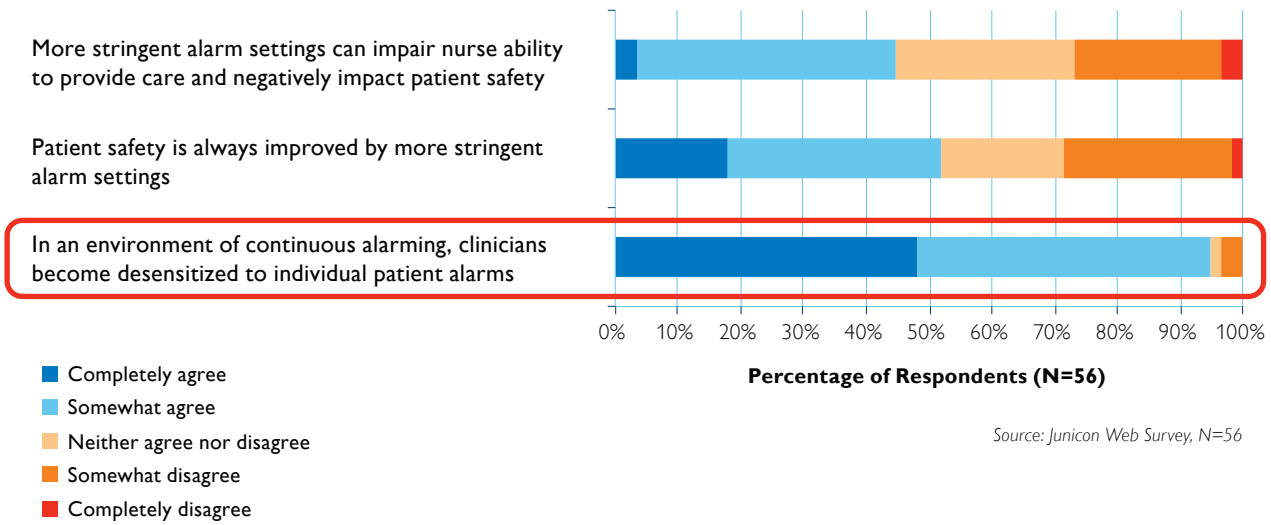


Figure 10: Nurses directly acknowledge desensitization.

The consequences of excess alarms: Self-defeat

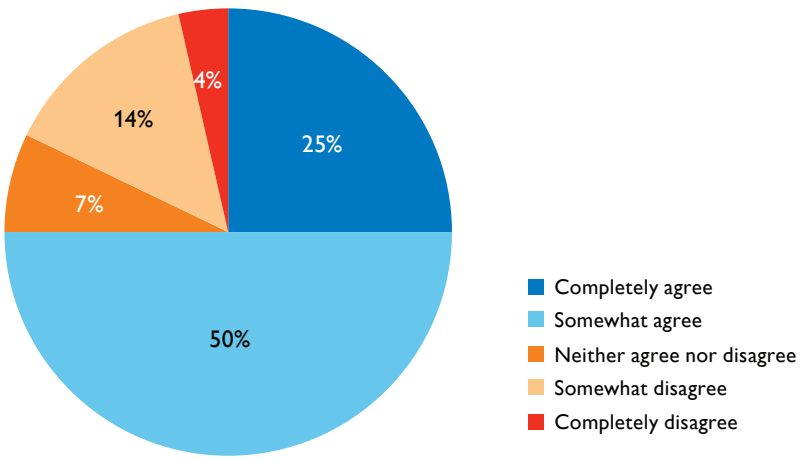
Alarm signals can be problematic when they are inaudible, indistinguishable, or duplicative

Alarm signals need to be able to compete with environmental noise in the hospital. **Sobieraj et al, 2006** found that while alarms were sufficiently audible when the doors to patient rooms were open, when the doors were closed alarm signals were poorly audible to nurses standing next to the room. For one room in this study, the distance from which the alarm could be heard decreased from 89 feet to only 5 feet just by closing the door. The same study also found that during floor buffing alarm signals could not be heard at all by the nurses. Alarm signals should better convey the urgency of the condition, be more distinctive, and easier to localize in a noisy environment.

Many machines generate similar sounds making it difficult for healthcare professionals to pinpoint which device the alarm signal is coming from. According to **McNeer et al, 2007** humans can only distinguish between 5 and 7 sounds. This is problematic for nurses who need to distinguish between many audible alarms. **Chambrin et al, 1999** found that even experienced nurses can only recognize 38% of vital alarms. In a study by **Cropp et al, 1994** it was found that 43% of alarm signals could be identified correctly. Only 4.5% of nurses studied by **Wee et al, 2008** were able to distinguish 100% of the alarm signals.

Alarm sounds can come from many sources for a single patient. Different machines monitor different conditions and sometimes different machines monitor the same conditions. As a result one 'not-to-exceed' parameter can trigger others generating multiple alarm sounds (**Block et al, 1999**). **Chambrin et al, 1999** noted that there can be as many as 40 different alarms monitoring vital signs.

As alarm sounds proliferate, duplicate and replicate one another, it becomes increasingly difficult for humans (i.e., clinicians) to process them effectively as calls for their attention. A frequent response has been to increase the volume of critical alarms, but typically this is self-defeating as the effect is identical to people trying to shout over each other to be heard.



Turning up the volume on alarms does not change the pattern of response to them.

Figure 11: Loud alarms can be self-defeating.

The consequences of excess alarms: Consumption of healthcare resources

Responding to alarms can occupy a significant proportion of nurse time

Responding to an alarm requires attention, and specific actions from the responding clinician, even in a non-actionable alarm. Most often, a nurse will need to attend the patient bedside, assess the cause of the alarm, review other patient parameters, and silence the alarm. If the alarm is genuinely actionable, more time is taken, as a change in the patient care course needs to be initiated.

Depending on the layout of a hospital unit, the presence or otherwise of a central station on the unit, and the clinical actions prompted by an alarm, this response cycle can take a few seconds, several seconds, or even minutes.

A simple mathematical model can show that as alarm frequency increases, the proportion of nursing time spent on responding to alarms rises depending also on the time taken to respond to each alarm. In extreme situations, (such as the charge nurse facing 4 alarms / minute in the hospital audited by Philips) the model can approach or exceed 100%.

Most of this time is wasted in a non-actionable alarm

If the alarm is indeed actionable, then this time is well spent, because attention was warranted and the clinical course for the patient is changed. If the alarm is not actionable, but still carries relevant information, then the time spent is of some value, as the clinician has important new knowledge about the patient, which may influence the interpretation of future signals.

If, however, an alarm is not relevant (i.e., a pure 'nuisance' alarm), then much of this time is wasted. Responding to such an alarm can lead nurses to spend time with patients that they would not otherwise have prioritized, and this may occasionally lead to accidental discoveries of clinically relevant information. More often, however, the time will be taken away from other nursing tasks, including providing care to other patients that were prioritized more highly.

How Much Time Could Non-Actionable Alarms be Wasting?

In Junicon's web survey, critical care and acute care nurses reported an average of **68 seconds** between alarms that they personally responded to during their shift. The same nurses also reported that each alarm takes an average of **15 seconds** to respond to.

Although this is self-reported data, and is not standardized to reflect different shift intensities, it gives a possible indication of the burden of non-actionable alarms in terms of nursing time. If **15 seconds** out of every **68** for every nurse are spent responding to an alarm, and approximately **50% are non-actionable** (Table 1), then by implication, **11.08%** of nursing time is spent on responding to non-actionable alarms.

Lost nursing time is expensive

If it is true that nurses are spending an average of **11% of their total working day** on responding to alarms that are not clinically relevant, then it would be reasonable to assume that ~11% of all spending on nursing salaries, training and benefits is consumed by non-actionable alarms.

Even if this estimate, based on self-reported data, were substantially wrong, it is clear that non-actionable alarms absorb millions of dollars of nursing time.

Lost nursing time is a lost opportunity

The hard cost of nursing time may grossly underestimate the true cost of non-actionable alarms in nursing time. For as long as the USA has a nurse staffing shortage, demand for nurse time exceeds supply, indicating that there are valuable tasks that are not executed because of scarce time. Freeing up 10% of nursing time could allow for more time for training, or technology implementation. It could be deployed in more attentive interaction with patients, potentially improving patient experience and thus patient satisfactions scores. In general, it could be deployed in more pro-active patient care, improving quality of care in many small ways that can impact both patient outcomes and patient satisfaction. **Mitigating non-actionable alarms could therefore be viewed as a way to get ~10% more out of each nursing team member.**

The bottom line: The clinical consequences of poor alarm management costs patients and hospitals dearly

The impact on patients

Although it is not always clear how excessive alarms result in adverse clinical outcomes, it is clear that poor alarm management (whether excessively sensitive, or not sensitive enough) can lead to missed events, including codes, and even fatality. It is also clear that the overall care experience of patients and families can be adversely affected by an environment of noise and stress. From the patient perspective, poor alarm management can result in:

- Missed alarms, leading to adverse events;
- Stress, interrupted sleep and delayed recovery;
- A less pleasant experience in the hospital;
- Unnecessary concern and distress for family members.

The impact on hospitals

For a hospital, poor alarm management has both direct and indirect consequences. The clinical outcomes of missed alarms can be severe, leading to adverse events and slower recovery. The consequences to a hospital can be wide ranging:

- Litigation, resulting in potential 7-figure liabilities;
- Sanctions from The Joint Commission if failing to meet performance requirements;
- Cost of unreimbursed care resulting from adverse events;
- Unanticipated transfers to the ICU;
- Extended overall length of stay.

A day of ICU care in the USA can cost the provider **>$3,500**, while each day on a medical/surgical unit costs **~$1,100 (Halpern et al, 2010)**. Anything that increases risk of ICU transfer or delays patient recovery has an immediate cost to hospitals.

Litigation can result in catastrophic losses, with median wrongful death settlements between **$500,000** and **$1,500,000**, depending on the state (http://www.verdictsearch.com).

Adverse publicity from a major event can have a dramatic impact on referrals, while decreased patient satisfaction from stress and noise can also affect volumes. With increased scrutiny from public and media on iatrogenic events and quality measures, preventing avoidable events is a critical priority. Furthermore, provisions of Accountable Care are leading to immediate financial consequences for avoidable drops in care quality, in the form of unreimbursed care episodes and penalty rates.

The clinical risks inherent in poor alarm management can thus have dramatic financial implications to hospitals.

Conclusions

1: The absolute burden of alarms in the hospital environment is problematic:
Alarm frequency is becoming unsustainable. Where individual nurses are required to field 3 or more alarms per minute, and where a single patient may generate >180 alarms over 24 hours, there is clearly a problem. Clinicians and administrators will ultimately be faced with a choice: Hire more people to field an ever growing clamor of alarms, or reduce the number of alarms

2: Half of all alarm signals are not clinically relevant:
Literature review shows that a large proportion of alarm signals are false or not clinically relevant. Although definitions vary between studies, it is clear that many alarms are not meaningful, and the proportion could be as high as 80%. In an environment where total alarm burden is problematic, minimizing non-actionable alarm signals will be of high value.

3: Excess alarms, particularly excess 'nuisance' alarms, are clinically harmful:
Excess alarms can result in conscious or unconscious desensitization among the clinicians that they are intended to alert. In this situation, they no longer function as effective alarms, and true positive signals are liable to be lost. The environment of constant noise can raise stress levels for patients, families and clinicians. In extreme cases, alarm fatigue results in breach of monitoring protocol, with potentially disastrous results. Responding to nuisance alarms takes time away from clinically valuable tasks, and the break in clinician concentration results in risks of other errors.

4: A large number of false positive alarms is operationally inefficient:
Responding to non-actionable alarms may consume 10% or more of nursing time in a typical unit. In situations of above average alarm frequency and/or a high rate of non-actionable vs. actionable alarms (which are often likely to coincide), this proportion could be 50% or higher. Time lost in this way can be valued in two ways – as a straightforward cost, in which ~10% of nursing wages are consumed on false alarms – or as an opportunity cost, in which the time is taken away from other tasks that can improve clinical and operational performance, and patient satisfaction.

5: There is a clear mandate to improve the management of alarms:
Improving the management of alarms is not synonymous with relaxing settings, or taking action to eliminate false positives. The problem of excessive alarming is multi-dimensional and requires a multi-dimensional solution. In some cases, major gains can be realized with simple changes – in other cases, more comprehensive changes to equipment, behaviors and culture are required. Managing the alarm environment is a serious undertaking that will often require substantial organizational effort, and change management. In order to maintain quality of care while changes are made, hospital administrators will need to be deeply engaged.

Recap: 12 reasons why improving alarm management should be a key priority for US hospitals today

1. There is clear evidence that alarm frequency in many clinical environments is excessive.
2. Most alarm signals are NOT actionable – 50-80% according to published literature.
3. Alarms cause stress for healthcare professionals, with sound levels of 80 decibels common in clinical units.
4. Alarms stress patients and interrupt sleep. Stress and poor sleep can impact recovery, extend length of stay and result in worse long term function.
5. Alarm fatigue results in depression and reduced productivity in nursing staff. More than 50% of nursing staff identify themselves as affected by alarm fatigue.
6. Background noise, signal overload and alarm fatigue can lead to unconscious filtering, destroying the function of alarms and increasing the risk of missing a critical notification.
7. Alarm fatigue can lead to conscious filtering, including disabling and silencing alarms, that increase the risk of missing a critical notification.
8. Increasing the frequency, priority and volume of alarms to overcome alarm fatigue is a self-defeating strategy – you can't shout over the crowd.
9. If a critical notification is missed, patients may die, litigation can cost millions of dollars, and the image of a hospital can be tarnished irrevocably.
10. If a sub-critical notification is missed, patients may recover more slowly, with extended length of stay, and possible transfer to critical care settings.
11. Decreased patient satisfaction and adverse publicity from quality-failure events can impact referrals to a hospital.
12. Non-actionable alarms waste substantial nursing resources today, costing the healthcare system billions of dollars each year.

In addition to these compelling reasons, hospitals now face a direct requirement to meet a National Patient Safety Goal from The Joint Commission.

How many of these reasons apply to your facility? Is alarm management more of an issue than you thought?

Read the Philips White Paper on taking steps to improve alarm management.

Appendix: detailed descriptions of purpose and methods

Philips Focus

Philips Healthcare has always had a strong commitment to providing solutions that help hospitals improve their quality performance. As the leading provider in patient vital signs monitoring, Philips is a direct participant in the provision of patient alerts, and is critically aware of the problem of excessive alarms. Philips has several major initiatives underway to address and mitigate the problem of non-specific alarming, including sensor and monitor technology, multi-parametric intelligent alarming, alarm measurement and audit through the PIIC iX platform, IntelliSpace Event Manager, and consulting services to manage customer alarm settings.

Research into alarm management

In order to understand and quantify the clinical impact of managing alarm management, Philips has worked with Juniper Consulting Group, Inc. to better understand the topic. Juniper Consulting Group (Junicon) is a healthcare and life sciences consulting company, with practices in market research, strategy, and health economics & epidemiology. Together, Philips and Junicon conducted extensive research into current practices, expectations and beliefs of clinicians, and experiences with implementation of new practices. An extensive review of the evidence for alarm management was also conducted.

In light of the learning from this process, Philips has decided to share the results with US hospitals.

Methods

1: Literature Review

Junicon conducted an extensive review of the published literature on current patient alarm systems, alarm fatigue, and improvements that can be made to those systems. The PubMed database of abstracts and GoogleScholar was searched , and a list of search terms were varied to include “patient alarm(s)”, “hospital alarms”, “alarm fatigue”, “false alarms”, “nuisance alarms”, etc. References from studies retrieved under these search terms were also reviewed. Literature published between 1990 and August 2012 was considered.

2: Web Survey

Junicon also conducted a 20-minute web survey with 56 nurses who worked in acute, general floor departments. Respondents were drawn as a random sample from the Epocrates panel of >200,000 nurses. The first 56 sequential qualified respondents to an email invite were sampled. Interviews were completed between October 3rd and October 8th 2012.

3: Opinion Leader Interviews

In September and October 2012, Junicon held several extensive phone conversations with 9 clinicians that have published on the topics of alarm fatigue, alarm sensitivity and specificity, and alarm management improvement initiatives, as well as sites with experience in the organizational changes required when implementing new protocols.

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www.philips.com/healthcare
healthcare@philips.com

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