

# Taking alarm management from concept to reality: a step by step guide

## A quick survey:

In my institution:	Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree
Excessive alarms are a serious problem, impacting efficiency, but also quality of care and patient satisfaction	1	2	3	4	5
The increasing frequency and volume of alarms will ultimately be unsustainable	1	2	3	4	5
Recognizing the problem of excessive alarms is easier than finding solutions	1	2	3	4	5
Although we believe there are real solutions to the problem of excess alarms, we have had limited success in addressing the problem	1	2	3	4	5
In the absence of clear evidence-based protocols, it is hard to know where to begin with implementing an alarm management program	1	2	3	4	5
We are ready to take action on alarm management, but do not yet have a clear action plan	1	2	3	4	5

## Your score:

- >20** You are ready to tackle the problem of alarm management – read on for a step by step guide to improving alarm management in your facility
- <20** You may have a problem with alarm management that you do not yet recognize – we suggest you read Philips “Just a Nuisance?”

**PHILIPS**

# A problem that many recognize, but few have solved

## An unsustainable situation

In an audit conducted by Philips Healthcare at one customer site, a Telemetry Charge Nurse was found to be receiving and responding to an average of **3.7 alarms per minute** over the duration of the audit. Even allowing for minimal time to respond to each alarm, it is clear that this situation was problematic. A majority of that nurse's time was spent responding to alarms, and inevitably some were missed.

Not every hospital or department has reached such a point, where the alarm environment reaches crisis. But most identify that excessive alarming is a problem, and many recognize that the current trajectory points inevitably towards a future breaking point unless concerted action is taken.

## Headed towards crisis

The logic of inevitable crisis is simple: 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. This focus is perfectly rational for each individual device, but creates an irrational situation in the aggregate. Although clinicians can change settings to rationalize the alarm environment, adjustments are rarely made.

If an event from alarm fatigue or mismatched settings occurs, the most common response has been to **INCREASE** the sensitivity of settings, **RESTRICT** ability to modify them, and **TURN UP** volume. In effect, there is a one-way street.

## Much progress, but no easy answers

As alarm management has become a topic of increasing priority in the US healthcare system, many solutions have been proposed, and results of specific interventions studied and reported. Positive results have been reported from a wide range of interventions – from very simple (changing EKG electrodes daily) to technologically sophisticated, proprietary approaches (multi-parameter alarms and 'alarm of alarms'). Many approaches entail solutions that cannot be easily duplicated, or that are specific to the care setting in which they were studied.

Today, relatively few hospitals have developed comprehensive programs to manage their alarm environment. More often, alarm management is occurring at the level of individual departments, or even individual nurses. Ad hoc solutions to excessive alarms, including unsanctioned adjustments to alarm settings, can be as much part of the problem as the solution.

# Background: There is wide acceptance that excessive alarms are a real problem

## More than just a nuisance

In Junicon's Web Survey, a majority of nurses indicated that they perceive alarm management to be a major issue, with serious clinical consequences beyond the simple inconvenience of distraction. However, although the consequences of alarms are acknowledged, and the nursing community is ready to address the problem, easy fixes are hard to find.

## A nursing management issue

8 Chief Nursing Officers also completed Junicon's Web Survey, and their responses were even more pointed than those of department nursing. CNOs are aware of the clinical, operational and human resource impacts of excessive alarming, and are seeking ways to address it in ways that do not compromise patient care.

### Nurses generally accept that alarming is a real clinical and economic problem...

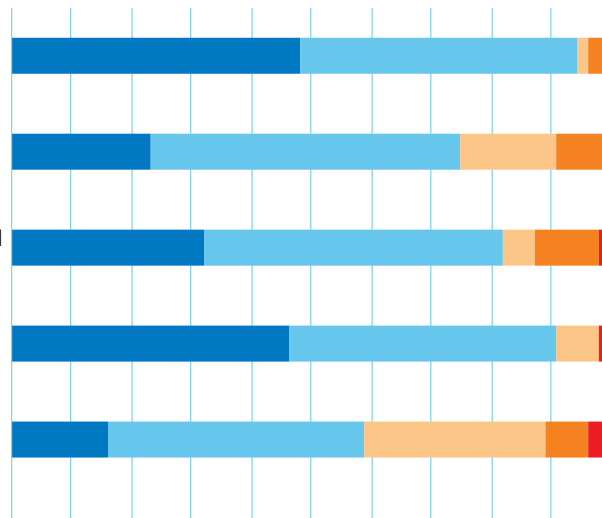
In an environment of continuous alarming, clinicians become desensitized to individual patient alarms

False and nuisance alarms can have important clinical consequences

False and nuisance alarms contribute to delayed response time to truly 'actionable alarms'

False and nuisance alarms contribute to increased psychological stress among healthcare workers, patients and families

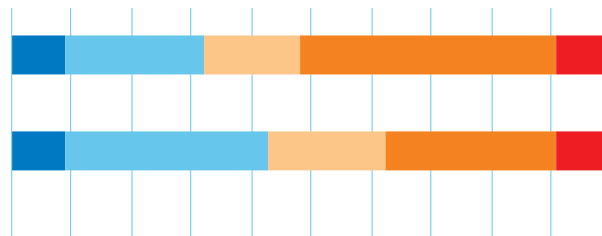
False and nuisance alarms contribute to increased costs to the hospital



### ...and refuse to accept excessive alarms as 'just part of the job'...

Constant alarming is something nurses have to learn to live with

A high number of false alerts is just an inevitable consequence of providing highest quality of care



### ...but do not feel that there are easy answers available to solve the problem.

False and nuisance alarms are an easy problem to fix

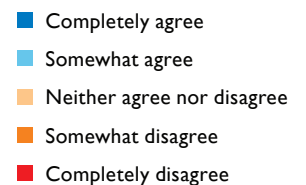
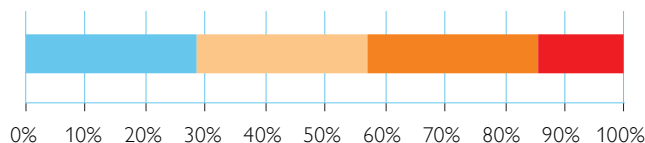


Figure 1: Nurses recognize alarms as more than just 'a nuisance'.

Source: Junicon Web Survey, N=56

# Background: The joint commission is requiring action

## A demand for action...

In June 2013, The Joint Commission published a National Patient Safety Goal on Alarm Management (NPSG.06.01.01). The goal has explicit performance requirements that are effective from January 2014, some of which will be measured in the calendar year 2014. Others will be measured from 2016. Furthermore, the Goal indicates that future requirements are possible or even likely as best practices become clearer.

Therefore, US hospitals will be subject to performance evaluation by The Joint Commission on specific features of alarm management. In 2014, hospitals will be required to establish alarm management as a key priority, and to have identified necessary alarm management priorities based on real data specific to their environment.

## ...Appropriate to each hospital

Thus far, the Joint Commission does not have standardized evidence-based recommendations on best practices for alarm management – other than to take it seriously and establish a strategy. NPSG.06.01.01 recognizes that best practices in alarm management are hard to define, and need to be adjusted for the unique conditions of each individual hospital or unit: “... issues vary greatly among hospitals and even within different units in a single hospital.”

## Do something. Anything?

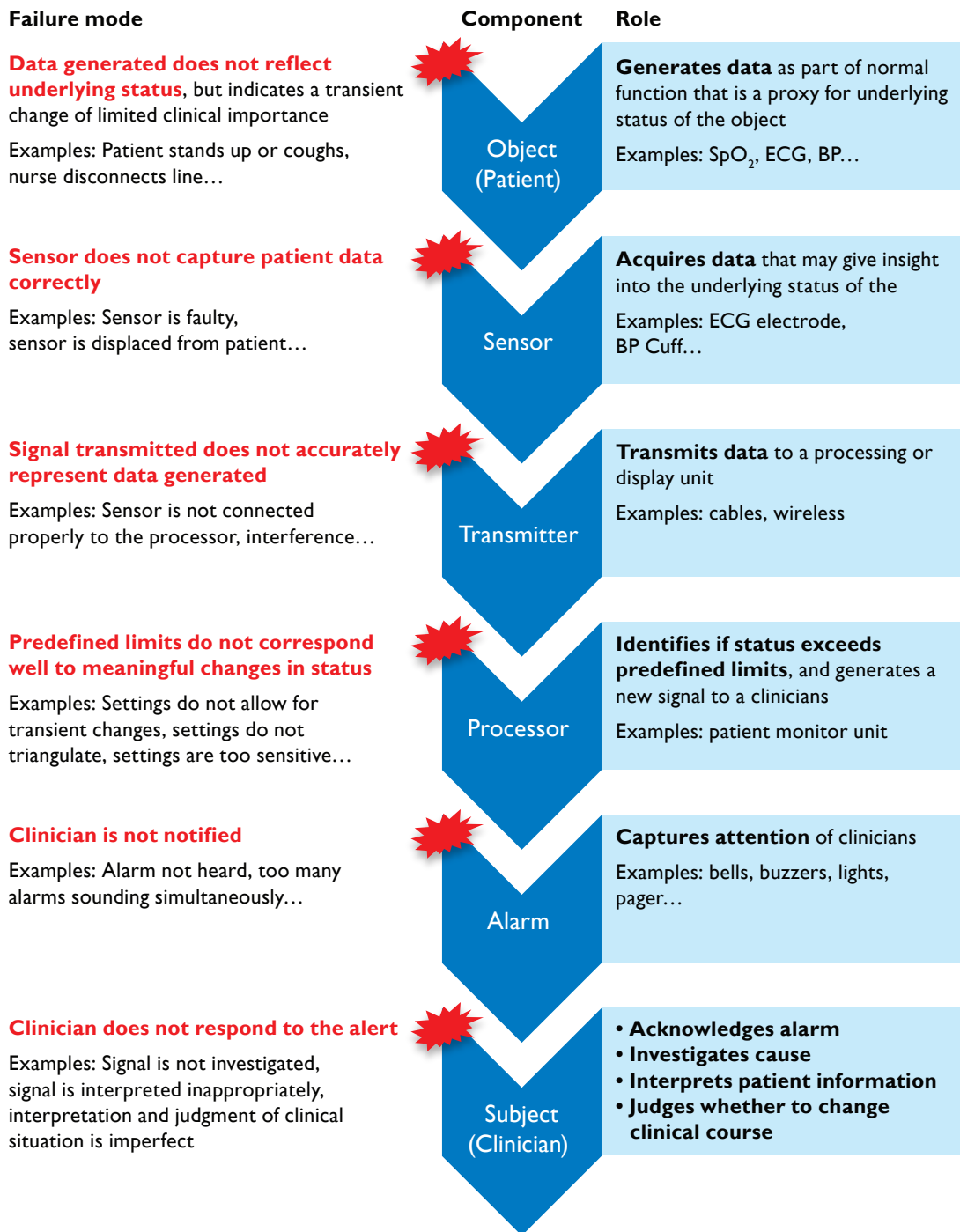
The challenge for hospital managers is now to formulate a coherent strategy for alarm management **grounded in a data-based understanding of the specific**

**alarm environment** for which they are responsible. Without clear, universal best practice guidelines, responsibility for determining the best approach for each facility is going to fall on the leadership of that facility. Managers are now faced with a need to respond to The Joint Commission’s NPSG, but without specific guidance on what a response needs to include. An effective approach will require a thorough understanding of the current alarm environment, and a rational strategy to focus on top priorities and root causes.

“There is general agreement that this is an important safety issue. Universal solutions have yet to be identified, but it is important for a hospital to understand its own situation and to develop a systematic, coordinated approach to clinical alarm system management. Standardization contributes to safe alarm system management, but it is recognized that solutions may have to be customized for specific clinical units, groups of patients, or individual patients. This NPSG focuses on managing clinical alarm systems that have the most direct relationship to patient safety. As alarm system management solutions are identified, this NPSG will be updated to reflect best practices.”

*The Joint Commission NPSG.06.01.01*

# Background: excessive alarms can have many causes...



**Figure 2:** Possible failure points in the alarm pathway.

# ...and many possible solutions

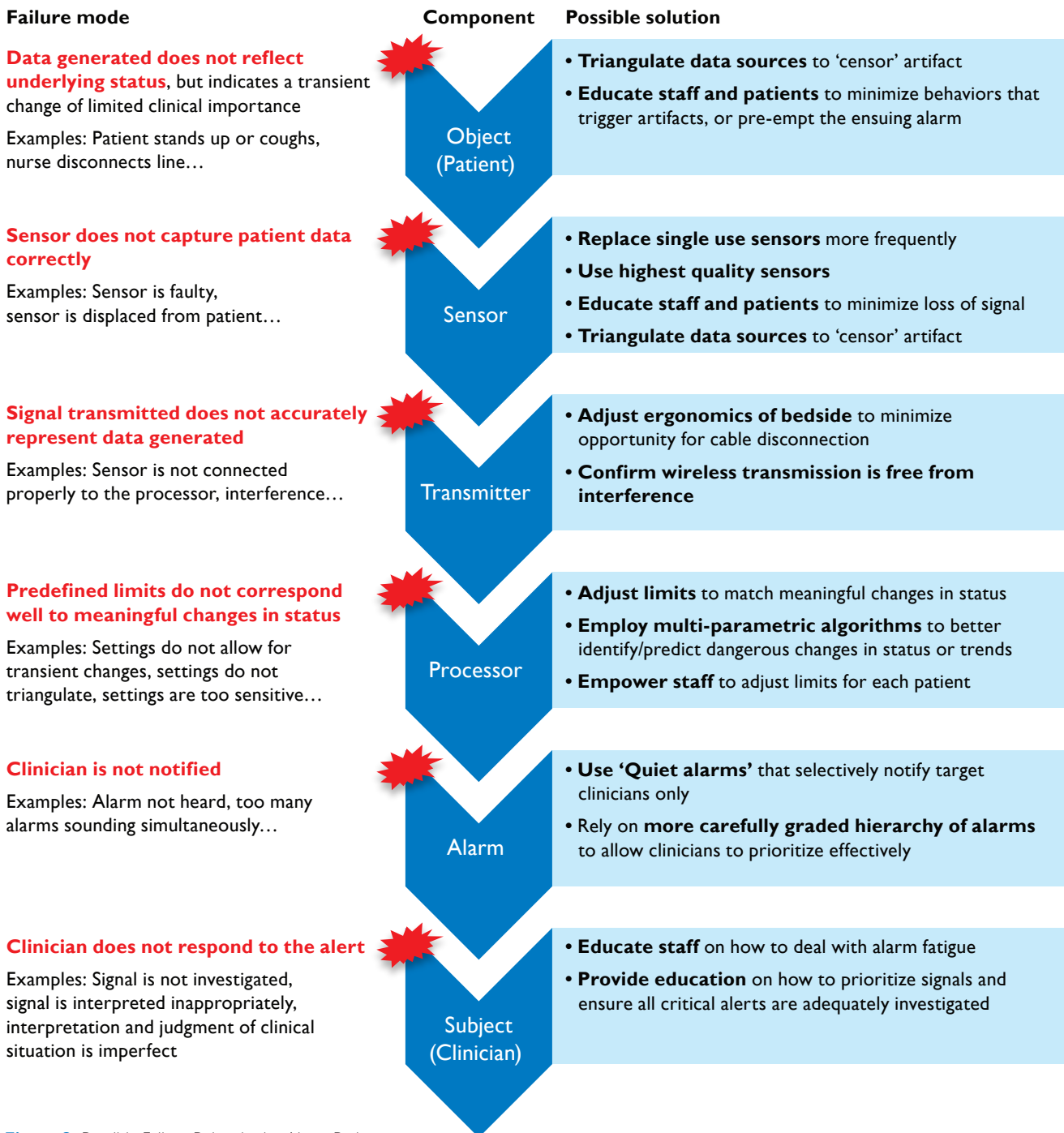


Figure 3: Possible Failure Points in the Alarm Pathway

# Literature review identifies many technology based solutions...

## Filtering technology can improve the yield of alarm settings

Not all patient populations are alike. Settings may be too sensitive for some populations leading to high alarm loads and non-actionable alarm signals. Algorithms, filters or customization of limits can reduce alarm load and false alarm signals without reducing sensitivity or specificity.

Customizing alarm limits increased the positive predictive value of an alarm signal by 31.9% in a study by **Schoenberg et al, 1999**. A study by **Gross et al, 2011** found that alarm load can be reduced by customizing the alarm settings to the population in which they are used. A change in the heart rate limit from 120bpm to 130bpm reduced the alarm load by more than 50%. **Graham et al, 2010** showed that educating nurses to customize alarm parameters reduced alarm load by 43%.

Similarly, new algorithms and filters can reduce unwanted false alarm signals. Fuzzy logic algorithms, which follow probabilistic reasoning rather than exact, have had success in some studies.

**Otero et al, 2009** found that applying a fuzzy logic algorithm produced only 7% false alarm signals. **Oberli et al, 1999** found a reduction in false alarm signals from 75% to 1%, an increase in sensitivity from 79% to 92% and an increase in positive predictive value from 31% to 97% by applying a fuzzy logic algorithm.

A logic algorithm was used in a study by **Schoenberg et al, 1999** to increase the urgency of the alarm signal based on the number of times that alarm signal has occurred. It resulted in a tenfold increase in positive predictive value from 3% to 32%.

## Technology can help also help eliminate artifact

In a paper written by a Johns Hopkins team, *Using Data to Drive Alarm System Improvement Efforts*, nurses stated that they were more likely to respond to alarm signals if the overall alarm load was decreased. Their study resulted in increased patient safety and decreased environmental noise by switching to disposable leads and using a multi-parameter algorithm. Overall alarm signals were reduced 41% per bed per day.

Similarly, a pre-alarm signal delay can be introduced to suppress motion artifacts from patient movement. **Chambrin et al, 1999** reported that 52% of alarm signals were as a result of patient motion. **Makivirta et al, 1994** found that by increasing the pre-alarm signal delay from 5 seconds to 10 seconds reduces alarm load by 26%. **Gorges et al, 2009** applied a 14 second and 17 second pre-alarm delay and reduced non-actionable alarm signals by 50% and 67%, respectively.

Study	Before alarm adjustments (%)	After alarm adjustments (%)
Aboukhalil et al, 2008	42.7	17.2
Oberli et al, 1999	75	1
Otero et al, 2009		7
Study	% Reduction	
Hu et al, 2012	2.2-11.2	
Cvach et al, 2013	46	

**Table 1:** False Alarm Signal Reduction

# ...while key alarm management bodies identify a multitude of potential interventions

## Effective alarm management:

### Recommendations from the literature

#### Environmental changes:

(Healthcare Technology Foundation: 2006 National Survey on Clinical Alarms)

- Better design of facilities
- Communication
- Monitoring (rounds)

#### Administrative changes:

(Healthcare Technology Foundation: 2006 National Survey on Clinical Alarms)

- Evaluate Purchase items for usability
- Test alarms in their environment
- Software setup/ testing

#### Care management and staff changes:

(Healthcare Technology Foundation: 2006 National Survey on Clinical Alarms)

- Training
- Monitoring (rounds)
- Use best practice guides
- Institutional standards

## Device design improvements:

Joint commission 2006 national patient safety goals and expectations

(<http://www.jointcommission.org>)

- Goal 6: Improve the effectiveness of clinical alarm systems
- Requirement 6A: Implement regular preventive maintenance and testing of alarm systems
- Requirement 6B: Assure that alarms are activated with appropriate settings and are sufficiently audible with respect to distances and competing noise within the unit

## Medical warnings will be more effective if:

(Edworthy et al, 2005)

- Warning sounds are standardized
- The acoustic properties of alarms are given proper consideration
- The learnability of alarms is given proper consideration
- Prioritization of alarms is possible within the system
- The urgency of alarm sounds matches their criticality
- Trigger points are appropriately set
- Intelligent alarm systems are used

## Elements of alarm system performance

that are needed to be an effective alarm (Imhoff et al, 2009)

- Detection of life-threatening situations
- Detection of life-threatening device malfunction
- Detection of imminent danger early
- Detection of imminent device malfunction
- Diagnostic alarms that monitor pathophysiological condition rather than out-of-range variables.

## Actions to improve alarms

(Healthcare Technology Foundation:2006 National Survey on Clinical Alarms)

- Design
- Smart alarms
- Integration/remote
- Usability/human factors
- Standards

## Characteristics of an ideal alarm sound

(Edworthy et al, 2006)

- Easy to localize
- Resistant to masking by other sounds
- Allows communication
- Easy to learn and retain

## Recommendations to decrease alarm fatigue

(Cvach et al, 2012)

- Smart alarms can reduce the number of false alarms
- Alarm technology that incorporates short delays can decrease the number of ignored or ineffective alarms caused by patient manipulation
- Standardizing alarm sounds may be an effective way to reduce the number of alarms that staff must learn
- Animated steps on the monitoring equipment for troubleshooting alarms would be helpful in assuring best practice with equipment

“An ideal alarm system would only warn when appropriate; there would be consistent use of the same alarms for the same functions regardless of organization or manufacturer; the urgency of alarms would be appropriate to their function; false alarms would be rare rather than common; and the alarms would be easy to learn and retain..”

*Edworthy et al, 2005*



# Learning from those with more experience is challenging: Wisdom is often too general, or too specific



**Fig 4:** Word cloud analysis of recommended actions in 2011 AAMI, FDA, TJC, ACCE, and ECRI Institute Alarms Summit.

## **Actions taken by hospitals participating in Junicon's web survey**

- Making sure alarm setting are the right ones for each patient.
- Appropriate patient sensitivity settings and of course purposeful hourly rounding.
- Hospital has reevaluated the alarms that are sent to spectra link phones. Also evaluated and reduced which alarms are sent to phones. In the NICU we have changed our saturation alarms to be severe low alarms
- Parameters are pt centered and adjusted at each change of shift based on previous 12 hrs worth of data
- Ensuring alarms are individualized for each patient.
- Making sure the alarms are set correctly and also making sure that there is no defect to the products.
- Different alarms so that people don't become immune to them and ignore them, or different sounds to determine which is a bed alarm vs a call light, bathroom, IV, vent or monitor alarm
- Setup alarm protocols with specific times where alarm parameters needed to be reassessed.
- Change limits on overly sensitive alarms. Encouraging staff to take appropriate measures to prevent alarms
- We had pump leasing company exchange and service all pumps to ensure accuracy. We also have increased Nursing in-services on ways to prevent alarms.
- Evaluate settings, provide education on proper use of monitors & alarms
- More specific alarm settings. New monitors. Better sensitivity.
- Patient education on why alarms are used as well as utilizing different alarm technology. We have also started to assign "zone coverage" for alarms, so floor staff are assigned zones to cover alarms instead of covering just for their patient assignment.
- Adjusting preset parameters to eliminate nuisance alarms without impacting critical alarms
- We are trying to be more proactive with hourly rounding and checking with patients before the alarms sound, when possible.

# A path forward: What approaches can be generalized?

## A need for a comprehensive approach, but a shortage of solid guidance

While many investigators have shown their results, there is no one study that shows ‘the universal best practice in alarm management’. It is a truism that alarm settings that work effectively in one clinical department and one typical patient population will not be appropriate for others.

However, it is clear that successful intervention in alarm management should be led proactively rather than deferred to organic solutions that evolve at the point of care. There is an enormous amount that can be learned from solutions and workarounds on the unit, and many of the best approaches will come from common-sense practices at the point of care. However, for a hospital

striving to provide quality of patient care, efficiency, and adherence to best practices throughout the facility, it is critical that the hospital administration understands and leads the change. Particularly for approaches that may change the balance between sensitivity and specificity in patient monitoring, it is vital for the hospital to approach alarm management in a programmatic way.

This then has been the challenge for CNOs, Department Heads and Quality Managers in hospitals across the USA. There is a clear mandate to lead change in terms of alarm management, but **with no clear, evidence-based best practice, it can be challenging to know how to begin tackling the problem.**

## Searching for consistency in alarm management solutions

In order to understand the underlying principles and success factors, a three-pronged approach sought out consistent factors in successful alarm management:

- A comprehensive literature review was conducted, looking at published papers on interventions to reduce alarm burden and/or improve the yield of alarms.
  - 9 authors and wider opinion leaders were interviewed to understand their approaches to alarm management, and capture lessons learned on how to approach an alarm management intervention.
  - A thorough internal review of Philips experience with alarm management – quantification, diagnostics/audit, and interventions – was completed.
- Our conclusions are presented below.

### A path forward: 4 steps for a successful program

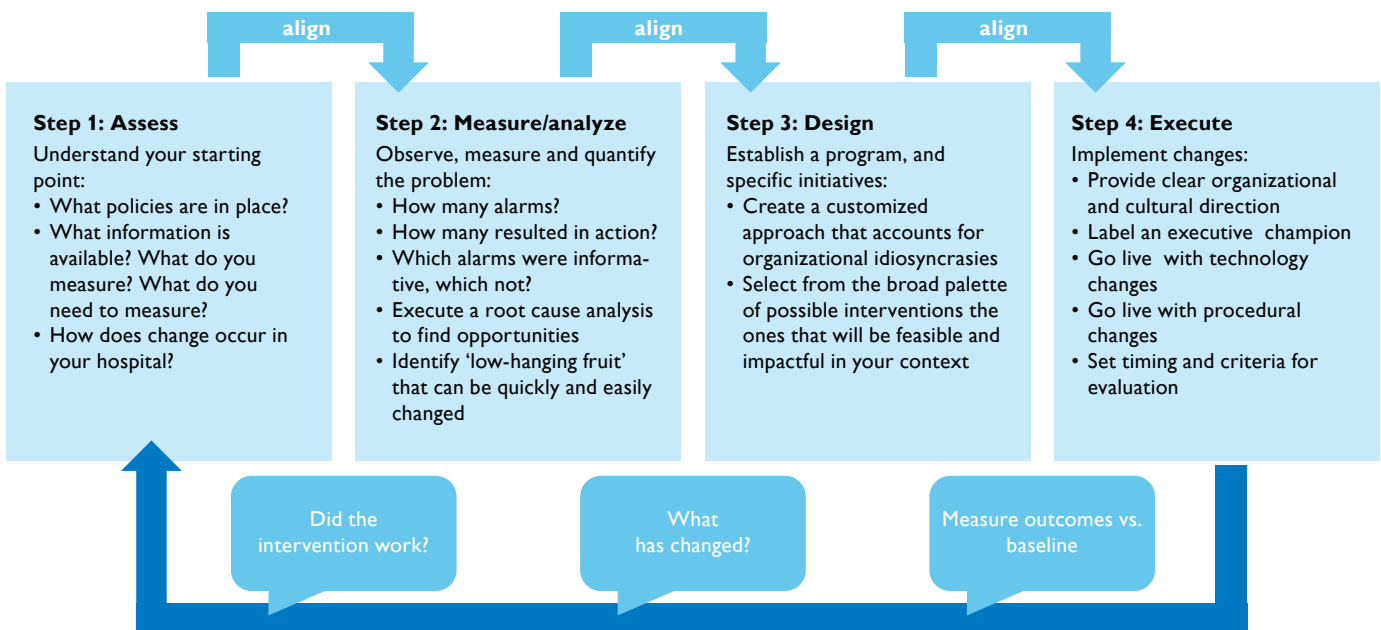


Fig 5: 4 steps for a successful alarm management intervention.

# Step 1: Assess

## Understanding the baseline is critical

Before undertaking any program to address alarm management, a hospital needs to understand the starting point, from an organization and demographic perspective.

**It is highly likely that any program to improve the alarming environment will involve CHANGE MANAGEMENT.**

In order for change management to be successful, it is critical to understand the starting point for the organization.

Documenting the 'way things are' makes it possible to successfully change them, and can identify potential landmines. Understanding how change happens is also vital.

Critical things to understand include:

current processes, policies, and culture.

Simply documenting product inventory and current settings on devices that alarm provides a baseline. Understanding what information is available within the hospital, and what resources can be dedicated to measuring, analyzing, designing and

implementing a solution, is also critical; if resources and data are not readily available, then the hospital may need to consider approaching outside experts for help.

## Key determinants of success that Philips has observed:

- Objective observation and documentation of policies and procedures is critical: a third party can benchmark against a wide experience of hospitals, and identify unusual or innovative practices.
- Product inventory should be executed by professionals with deep knowledge of equipment: it is necessary to understand not just models and current settings of equipment, but also possible configurations and software settings.
- A third party can provide an objective insight into culture and organizational readiness: hospitals and healthcare systems differ dramatically, and many

factors influence readiness for change.

There is a great opportunity to learn from the experience of others.

- Observation and measurement needs to be positioned carefully with staff: it is critical that the clinical team do not perceive measurement as a 'hostile audit', in which they have more to lose than to gain.

"Then you also have a major problem in many care settings where you may have, and we discovered this in my own hospital, you may have 5 different kinds of telemetry monitoring equipment, because you buy a few pieces of new equipment, but don't replace everything. Each time you don't necessarily buy from the same vendor. All different types may sound differently, all which have different methods for setting parameters and for the alarms going off."

*Jane Barnsteiner, PhD, RN, FAAN*

# Step 2: Measure and analyze

## Measurement is needed to build consensus

Even if the organization is aligned around the need to tackle alarm management, it is critical to build alignment on how to do so. Different stakeholders may have different perceptions of the problem, and key decision makers may have limited appreciation for the realities of the alarm environment on units. Measurement is the bedrock of consensus, getting all stakeholders on the same page. Frequently, the administration and the clinical team alike will be shocked at the stark numbers: 100s of alarms per bed per day; less than 30% of them actionable...

"If I were at a community hospital, number one I would need to be able to measure what is currently happening and that's not even happening at hospitals. Most hospitals don't have the ability to measure their problem."

*Maria Cvach, MSN, RN, CCRN*

## Analysis is needed to form the basis for action

A solid action plan must be founded on the most pressing priorities. Alarm event statistics can identify the culprit alarms and situations in which non-actionable alerts are most frequent, enabling clear prioritization to focus on a manageable scope that will have highest impact. Root cause analysis is needed to determine the least disruptive solution to each problem – the same issue might be addressed by changing settings, adjusting response protocols, or by a different sensor placement technique – but these could have radically different impacts on clinical workflow, staff education, and patient safety.

## Key determinants of success that Philips has observed:

- **It takes someone with deep knowledge of equipment and systems to pull accurate and relevant data:** a third party can benchmark against a wide experience of hospitals, and identify unusual or innovative practices.
- **Building a 'value stream map' is a great way to understand and communicate proposed change:** a 'before' and 'after' schematic of workflow can be posted in nursing staff rooms as a constant reminder of how daily change works towards a future goal.
- **Consensus can be built by providing clear materials for everyone in the hospital to refer to:** a visual guide to the change process is great tool for getting everyone on the same page, and clearly illustrating irrational aspects of current workflow.

## Step 3: Design

### A careful plan is necessary to ensure effective change management

Change management frequently fails due to inadequate preparation, unrealistic expectations, and underestimation of the resources required to implement change. Therefore, a realistic plan is required before embarking on any major steps. Not only is it critical to identify **what** will be done, but also **who** will do it, **when**, and with **what resources**. Realistic expectations about what can be achieved, and how much effort is required to execute effectively. Ineffective execution may be worse than no action at all – in part because it can poison enthusiasm for further change. A champion and a project team should be identified, and time allocated. A formal project plan is needed, with process owners and timelines. External partners

should be identified, and charters set. Without a formal plan, execution is likely to be half-hearted and delayed, implemented in the rare ‘gaps’ between day-to-day activities. Without clear responsibilities and timelines with accountability, tasks will slip, and without broad education and engagement, initiatives will fail through incomplete compliance and inconsistent deployment.

### Key determinants of success that Philips has observed:

- **Change management should draw on lessons from similar experiences in different institutions:** include team members or advisors who have seen how similar changes have played out in other institutions: there are pitfalls and mistakes that can be easily avoided by taking note of the experience of other institutions.

- **A realistic evaluation of available resources is important to set a plan that can truly be realized before energy and enthusiasm fade:** many efforts to change clinical practice fail because lack of dedicated resources and demands of a day job result in a loss of momentum and slow progress. Realistic expectations and willingness to engage external resources are vital to prevent disillusionment.

“You can’t just buy an ‘out of the box’ solution, and you can’t just widen alarm limits indiscriminately. You need to really think about what your situation is, and make intelligent changes.”

*James Blum, MD*

## Step 4: Execute

### Execution requires continuing attention and effort

Change management should draw on lessons from similar experiences in different institutions: include team members or advisors who have seen how similar changes have played out in other institutions: there are pitfalls and mistakes that can be easily avoided by taking note of the experience of other institutions.

A realistic evaluation of available resources is important to set a plan that can truly be realized before energy and enthusiasm fade: many efforts to change clinical practice fail because lack of dedicated resources and demands of a day job result in a loss of momentum and slow progress. Realistic expectations and willingness to engage external resources are vital to prevent disillusionment.

### Key determinants of success that Philips has observed:

- **Set realistic expectations:** few organizations change fast without painful disruption. Think what it would really take to even make a ‘simple’ intervention like changing policy on electrode utilization. Many stakeholders throughout the hospital could be involved, requiring changes to policies, procedures and contracts.
- **Obtain executive commitment:** changes may require alignment of multiple hospital functions, including purchasing, risk management, and the entire clinical team. Without executive commitment and a clear mandate, the implementation team may struggle to get alignment.
- **Provide realistic resources to implement change:** an implementation team needs to be resourced with dedicated time allocation. The team needs to source the right set of capabilities, often from external resources – nursing education, biomedical/clinical engineering... Furthermore, time

needs to be budgeted for staff education beyond the implementation team, in trainings and workflow adaptations.

- **Assign change leadership accountability:** without a leader or leadership team with clear accountability, there is no impetus to keep change on track, and to overcome the likely hurdles that will emerge downstream. One approach to effective change management is to use an external resource to serve as a “lightning rod” in driving change and accepting accountability.

“What we found was that if you can correct the technical alarms you can get rid of a lot of patient alarms. We did a study in our hospital, just doing a simple intervention, just changing the electrodes every day. We found that if you have good electrode contact with the skin not only are you going to get rid of your technical alarms but you are going to reduce all of your patient alarms by about 50%.”

*Maria Cvach, MSN, RN, CCRN*

# Continuous requirement: Align!

## Repeatedly ensuring alignment is necessary for success

Obtaining alignment of stakeholders is a key step at the outset of any intervention to improve management of clinical alarms. Indeed, it may often be a pre-requisite: a minimum level of management engagement is needed to even begin the process of diagnosis and quantifying the problem.

Alignment can be facilitated by education and information. Many stakeholders, both among the administration and on hospital units, have a limited appreciation for the evidence and documented impact of excessive alarms. Educating a wider team can raise the profile of the issue and build agreement on the need to invest attention and resources.

Understanding the hospital starting point and capturing objective data in the 'Assess' and '**Measure/Analyze**' steps can further help drive consensus, as discussion focuses around objective realities in the hospital, and a need for change can be expressed in a quantitative way as a change from the current status.

By the time the hospital is in the '**Design**' stage, it is critical that no key stakeholders in the hospital remain in opposition to change, and that at least some clinical and administrative champions are committed to providing the attention and resources needed for change to be successful. In order to plan for resource requirements effectively, as well as to set timelines and metrics of success, a comprehensive alignment across the organization is necessary. All stakeholders need to sign-off on the project plan.

Once into '**Execution**', working to maintain alignment becomes even more important. Strains and pressures on consensus may emerge as the challenges of change are manifested in day to day work – new expenses for the administration, changes in workflow for the clinical team, requirement for special time to be dedicated for staff education and in-servicing, and various other tasks – expected or unexpected. This is the most sensitive time; where poor implementation and an unprepared team can lose alignment and the project can be derailed by loss of commitment and compliance.

“You have leadership who really walk the walk, they do rounds on the unit, they are talking with frontline people about the patient care challenges, they are learning about the safety challenges that staff have. In many of your magnet facilities you are going to find this. There are leadership teams in some places that are helping staff to put in systems that will help to reduce alarm fatigue. “

*Jane Barnsteiner, PhD, RN, FAAN*

# 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 a leading provider of equipment for monitoring physiological parameters, 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, 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 were searched using a variety of terms, including: “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.

## Bibliography

1. ECRI Institute, "Alarm Safety Resource Site", online, accessed 2012, [https://www.ecri.org/Forms/Pages/Alarm\\_Safety\\_Resource.aspx](https://www.ecri.org/Forms/Pages/Alarm_Safety_Resource.aspx)
2. Cvach, M., "Monitor Alarm Fatigue: An Integrative Review", *Biomedical Instrumentation & Technology*, July/Aug 2012, 268-277.
3. AAMI, FDA, TJC, ACCE, and ECRI Institute Clinical Alarms Summit 2011, [http://www.aami.org/publications/summits/2011\\_Alarms\\_Summit\\_publication.pdf](http://www.aami.org/publications/summits/2011_Alarms_Summit_publication.pdf)
4. Chambrin, M., et al. "Multicentric study of monitoring alarms in the adult intensive care unit (ICU): a descriptive analysis", *Intensive Care Medicine*, 1999, V: 12 E:12, pp. 1360-1366.
5. Schmid, F., et al. "The Wolf Is Crying in the Operating Room: Patient Monitor and Anesthesia Workstation Alarming Patterns During Cardiac Surgery", *Anesthesia & Analgesia*, Jan 2011, V: 112 E: 1, pp. 78-83.
6. Aboukhalil, A., et al. "Reducing false alarm rates for critical arrhythmias using the arterial blood pressure waveform", *Journal of Biomedical Informatics*, 2008, V: 41, pp.442-451.
7. Siebig, S., et al. "Collection of annotated data in a clinical validation study for alarm algorithms in intensive care—a methodologic framework", *Journal of Critical Care*, 2010, V: 25, pp. 128-135.
8. Blum, J., et al. "Specificity improvement for network distributed physiologic alarms based on a simple deterministic reactive intelligent agent in the critical care environment", *Journal of Clinical Monitoring and Computing*, 2009, V: 23, pp. 21-30.
9. Gross, B., et al. "Physiologic monitoring alarm load on medical/surgical floors of a community hospital", *Biomedical Instrument Technology*, Spring 2011, Suppl., pp. 29-36.
10. Hu, X., et al. "Predictive combinations of monitor alarms preceding in-hospital code blue events", *Journal of Biomedical Informatics*, 2012, V: 35 I: 5, pp. 913-921.
11. Borowski, M., et al. "Reducing False Alarms of Intensive Care Online-Monitoring Systems: An Evaluation of Two Signal Extraction Algorithms", *Computational and Mathematical Methods in Medicine*, 2011, V: 2011 Article ID: 143480, pp. 1-11.
12. Cropp, A., et al. "Name that tone: the proliferation of alarms in the intensive care unit", *Chest*, 1994, V: 105.4, p. 1217.
13. Solet, J., et al. "Managing alarm fatigue in cardiac care", *Progress in Pediatric Cardiology*, 2012, V: 33, pp. 85-90.
14. Varpio, L., et al. "The Helpful or Hindering Effects of In-Hospital Patient Monitor Alarms on Nurses: A Qualitative Analysis", *Computers, Informatics, Nursing*, 2012, V: 30 I: 4, pp. 210-217.
15. Korniewicz, D., et al. "A National Online Survey on the Effectiveness of Clinical Alarms", *American Journal of Critical Care*, 2008, V: 17, pp. 36-41.
16. Bliss, J., et al. "Behavioural implications of alarm mistrust as a function of task workload", *Ergonomics*, 2000, V: 43 I: 9, pp.1283-1300.
17. McNeer RR, Bohorquez J, Ozdamar O, Varon AJ, Barach P. A New Paradigm for the Design of Audible Alarms that Convey Urgency Information. *Journal of Clinical Monitoring and Computing*. 2007; 21(6):353–63.
18. Bitan, Y., et al. "Nurses' reactions to alarms in a neonatal intensive care unit", *Cognition Technology and Work*, 2004, V: 6, pp. 239-246.
19. Sobieraj, J., et al. "Audibility of Patient Clinical Alarms to Hospital Nursing Personnel", *Military Medicine*, 2006, V: 171 I: 4, pp. 306-310.
20. Wee, A., et al. "Are Melodic Medical Equipment Alarms Easily Learned?", *Technology, Computing, and Simulation*, 2008, V: 106 I: 2, pp. 501-508.
21. Block, F., et al. "Optimization of alarms: a study on alarm limits, alarm sounds, and false alarms, intended to reduce annoyance", *Journal of Clinical Monitoring*, 1999, V: 15, pp. 75-83.
22. Halpern, N.A., et al. "Critical care medicine in the United States 2000-2005: an analysis of bed numbers, occupancy rates, payer mix, and costs." *Crit Care Med*. 2010 Jan;38(1):65-71.

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