

AAMI FOUNDATION

National Coalition for Alarm Management Safety

SpO₂ Alarm Management Toolkit

**THE AAMI FOUNDATION
IS GRATEFUL TO ITS
COLLABORATING PARTNERS
for their support and help in
creating this toolkit**



ABOUT THE AAMI FOUNDATION

The AAMI Foundation is a 501(c)(3) charitable organization.

Its mission is to drive reductions in preventable patient harm and improvements in outcomes associated with the use of health technology.

The AAMI Foundation creates synergy between clinicians, researchers, regulators, biomedical and clinical engineers, industry, and patients, leading the nation to share and disseminate critically important information, building a body-of-knowledge addressing emerging and long-standing complex issues related to health technology. The Foundation accomplishes this by convening diverse expert stakeholders and engaging them in a collaborative, team-based approach to tackle specific issues in the development, management and use of health technology. The intended outcome is reduced preventable patient harm and improved patient outcomes.

To learn more about the Foundation and ways to become involved, visit www.aami.org/foundation.

To make a tax-deductible donation to the Foundation, visit my.aami.org/store/donate.

PERMISSION TO COPY

We encourage you to share this paper with your colleagues. You may freely reproduce this publication for educational purposes only, provided that proper attribution is made as follows: *Copied with the permission of the AAMI Foundation. This publication may not be sold in whole or in part.*

The views expressed in this publication do not represent the views of the AAMI Foundation. The work of the AAMI Foundation and its members is intended to be a helpful resource for healthcare delivery organizations, so that every organization does not have to start their technology management work from scratch. It does not constitute legal, regulatory, operational, medical, or procedural advice, nor does it constitute a standard of care. It is essential that each healthcare delivery organization assess the material in the context of its own organizational needs, culture, technology, and priorities.

ACKNOWLEDGEMENTS

This document was produced by members of the AAMI Foundation's National Coalition for Alarm Management Safety. The coalition, launched in 2014, is made up of clinicians, respiratory therapists, industry partners, researchers, and national patient safety organizations. It addresses ongoing patient safety issues associated with the management of clinical alarms and provides solutions to overcome those issues.

TEAM MEMBERS

Paul Batchelder (Clinimark)
Nancy Blake (Children's Hospital of LA)
Madge Buus-Frank (Vermont Oxford Network [VON])
Tobey Clark (University of Vermont)
Maria Cvach (Johns Hopkins Hospital)
Marilyn Flack (AAMI)
Marge Funk (Yale)
Linda Giles (transcriptionist)
Ky Harrison (transcriptionist)
Sherry Hendricks (Extension Healthcare)
Samantha Jacques (Texas Children's Hospital)
Ben Kanter (Sotera Wireless)
Douglas Laher (AARC)
Jenny McFarlane (Huntington Memorial Hospital)
Michael Mestek (Covidien)
Melanie Myers (Huntington Hospital)
Jim Piepenbrink (Boston Medical Center)
Julie Reisetter (Banner Healthcare)
Prasama Sangkachand (Yale)
Sue Sendelbach (Abbott Northwestern)
Steve Treacy (GE Healthcare)
Steve Witz (Purdue)
Michael Wong (PPAHS)

EDITORS

James Piepenbrink, BSBME
Sue Sendelbach, PhD, APRN CNS, FAHA, FAAN

GRAPHIC DESIGNER

Yondee Designs, LLC

Published by

AAMI Foundation
4301 N. Fairfax Dr., Suite 301
Arlington, VA 22203-1633
www.aami.org/thefoundation
© 2018 AAMI

INTRODUCTION

The AAMI Foundation National Coalition for Alarm Management Safety* Saturation of Peripheral Oxygenation (SpO₂) Toolkit is designed to start your healthcare organization on a road to optimizing patient safety by providing you with resources, strategies, and approaches to mitigate non-actionable (clinically insignificant) SpO₂ alarm signals.

WELCOME

This toolkit provides resources to guide you from the start of a alarm management project to the final stage of implementation including sustainability. The intended recipients of these tools are members of an inter-professional team that is intended to be a working group of your organization's alarm management team including practitioners, nurses, biomedical/clinical engineers, respiratory care professionals, senior management, quality professionals and risk specialists. We welcome any feedback; reach out to [jpipenbrink@aami.org](mailto:jpiepenbrink@aami.org).

Managing pulse oximetry alarms involves both clinical and technical elements; workflow (order sets) and understanding what the alarms mean and how to work safely with the technology to make individualized changes to match patient conditions.

This toolkit provides information—data and experiences arranged in the 10 sections listed below— from a very diverse group of experts. As all healthcare organization systems and care areas are different, this toolkit will not provide a single “one size fits all” approach to solve all alarm management issues. This is not a discussion about what type of monitoring is better (surveillance, continuous or intermittent) but instead explains why alarms occur, the type and context, and how organizations can best utilize the technology they have to safely reduce pulse oximetry alarms.

Section I

HOW DO YOU GET STARTED?

Section II

WHO SHOULD BE ON YOUR SPO₂ GOVERNANCE TEAM?

Section III

HOW WELL DO YOU KNOW YOUR SPO₂ ALARMS?

Section IV

HOW DO SPO₂ ALARMS VARY? (VENDOR PERSPECTIVE)

Section V

HOW DO YOU GET THE DATA YOU NEED?

Section VI

HOW DO YOU RUN A PILOT TO EVALUATE YOUR PROPOSED INTERVENTIONS?

Section VII

HOW DO YOU DESIGN BEST PRACTICE ORDER SETS?

Profile of SpO₂ Pilot

PILOTING A PULSE OXIMETRY ALARM STUDY AT BOSTON MEDICAL CENTER

Section VIII

RESOURCES

Section IX

STRATEGIES

**sponsored by AAMI Foundation*

SECTION

I

HOW DO YOU GET STARTED?

The contents of the toolkit sections are arranged based on the tenets of the Joint Commission's National Patient Safety Goal NPSG 06.01.01.

Below are the "Elements of Performance" from the Joint Commission National Patient Safety Goal. In the right column are the sections of the tool kit with information provided and on the left column are how they are linked to the Elements of Performance from the National Patient Safety Goal.

READINESS ASSESSMENT

Joint Commission National Patient Safety Goal | 06.01.01

https://www.jointcommission.org/assets/1/6/NPSG_Chapter_HAP_Jan2017.pdf

EP	Elements of Performance	Tool Kit Section Comments
1	Leaders establish alarm system safety as a hospital priority	Section I – How do you get started?
2	Identify the most important alarm signals to manage based upon the following:	
<input type="checkbox"/>	Input from the medical staff and clinical departments	Section II – Governance
<input type="checkbox"/>	Risk to the patients if the alarm signal is not attended to or if it malfunctions	Section III – How well do you know your alarms?
<input type="checkbox"/>	Whether specific alarm signals are needed or unnecessarily contribute to alarm noise and alarm fatigue	Section III – How well do you know your alarms? Section IV – How do alarms vary by vendor? Section V – How do you get alarm data?
<input type="checkbox"/>	Potential for patient harm based on internal incident review	Section II – Governance
<input type="checkbox"/>	Publish best practices and guidelines	Section VIII – Resources
3	Establish policies and procedures for managing the alarms identified in EP2 above that, at a minimum, address the following:	
<input type="checkbox"/>	Clinically appropriate settings for clinical alarms	Section V – How do you get alarm data?
<input type="checkbox"/>	When alarm signals can be disabled	Section II – Governance
<input type="checkbox"/>	When alarm parameters can be changed	Section VI – How do you run a pilot? Section VII – Order sets
<input type="checkbox"/>	Who in the organization has the authority to set alarm parameters	Section II – Governance
<input type="checkbox"/>	Who in the organization has the authority to change alarm parameters	Section VI – How do you run a pilot?
<input type="checkbox"/>	Who in the organization has the authority to set parameters to "off"	Section II – Governance
<input type="checkbox"/>	Monitoring and responding to alarm signals	Section VI – How do you run a pilot?
<input type="checkbox"/>	Checking individual alarm signals for accurate settings, proper operation and detectability	Section V – How do you get alarm data?
4	Educate staff and LIP's about the purpose and proper operation of alarm systems they are responsible for	Section VI – How do you run a pilot?

Any alarm initiative should begin with an organizational assessment of the current practices as well as a review of risks associated with the technology, environment and staff expectations. The Joint Commission requires alarm management to be identified as a priority for the healthcare organization. After a review of the current environment, creation of proposed priority action steps related to risks and opportunities for improvement is necessary.

Here are some items for you to consider as you move through this analysis.

PHYSICAL ENVIRONMENT CONSIDERATIONS (E)

- Consider the physical environment; geography of the unit, (e.g., does the alarm just go off at the central station versus the patient room?).
- How does the size of the unit, layout of the patient rooms, and location of nursing stations impact the visibility of information from the hallway? Discover/Investigate how data are relayed to appropriate staff member.
- Does the alarm message show at bedside only?
- Is the alarm message relayed to a secondary device? (if yes, where is that device and is the right staff member carrying it?)
- Is there an alarm escalation process?
- What and how are data relayed to remote locations and in what timeframe?
- Is the alarm message relayed to remote monitors? Whose role/responsibility is it to view and respond to that remote monitor?
- Are all alarms generated relayed, or only critical alarms?
- How does that alarm alert? Light only vs light and tones/sounds?
- For those alarms where audio is chosen, how loud is the audio at each location audio? (e.g., bedside, remote display, secondary device, etc.)

- Are audible alarms easily differentiated against the overall noise on the unit?

PRACTICE CONSIDERATIONS (P)

- Understand the measurement and some of the clinical limitations and causes of alarms with pulse oximetry (see Section III).
- Identify parameter and alarm default variability as well as all filtering settings (delays, etc.) across patient care areas.
- Observe how staff respond to all alarm(s).
- Identify the number of non-actionable alarms (alarms associated with the SpO₂ monitor).
- Is there a specific policy for night time alarm volume?
- Who is responsible for responding to and silencing alarms? What is the escalation/backup plan when that person is not available?
- Is staff allowed to make patient specific alarm default changes?

TECHNOLOGY CONSIDERATIONS

Identify the different vendor products your institution may use to measure pulse oximetry. Vendors may produce different SpO₂ values so comparing one monitor against another is neither

a fair comparison nor an indication that either of them is “more accurate.” Vendors may address the following items differently, so understanding why these differences exist may help identify opportunities for staff education:

- What alarms are generated by the device?
- What are the differences in features and algorithms (e.g., alarm filtering, sensitivity and specificity)?
- What variability exists (i.e., differences in tones, etc.)?
- Does your current equipment have the ability to track desired data over time (e.g. frequency of alarms, reason for alarm, etc.)?

STAFF EXPECTATIONS

- Assess clinical staff understanding of various aspects of technology as well as staff expectation of the measurement (e.g., do staff understand the dissociation curve (please see Section VI Pilot) in clinical practice as well as identifying the types of alarms that occur (parameter alarms, technical alarms, and system alarms).
- Identify available sensor technologies for the varying patient populations and conditions (e.g., finger probe, forehead, disposable options, etc.).

SUMMARY

After evaluating the information above, identify opportunities for improvement and create a methodology to address gaps. Pilot projects, educational initiatives, on-unit huddles and other methods can be created to help influence change. It is important to ensure that senior leadership are engaged in any initiative to ensure that a logical process is created and followed and can be replicated across the organization. Additional information on leveraging alarm data, creating a pilot project and staff competencies are contained within the toolkit in Section VI.

WHO SHOULD BE ON YOUR PULSE OXIMETRY GOVERNANCE TEAM?

GOVERNANCE TEAM SELECTION

For **pulse oximetry**, creating a governance structure that includes specific departments and specialties is an important feature because of their reliance on pulse oximetry for their patient populations. The following is an example of a governance team looking at pulse oximetry alarms from Boston Medical Center.

ANESTHESIA	CLINICAL NURSE SPECIALISTS	PHYSICAL THERAPY/ OCCUPATIONAL THERAPY
BARIATRIC MEDICINE	EAR, NOSE, AND THROAT (ENT)	PULMONARY MEDICINE
CANCER CARE	INFORMATION TECHNOLOGY	RESPIRATORY CARE
CARDIOTHORACIC SURGERY	NURSE EDUCATORS	SENIOR MEDICAL RESIDENT
CHIEF MEDICAL OFFICER	NURSING LEADERSHIP	TRAUMA SURGERY
CLINICAL ENGINEERING	NURSE MANAGERS	LEADERSHIP



GOVERNANCE TEAM OBJECTIVES

Another important factor is to define objectives for the team so that a cohesive set of criteria are established before you create procedural initiatives.

1. Identify a goal statement such as reducing pulse oximetry non-actionable alarms by X%.
2. Ensure that the right level (e.g. intermittent versus continuous) of monitoring is available. Creating criteria for patient assessment and determining the level of monitoring required is an important step to ensure that organizations are not over monitoring patients which can result in increased non-actionable alarms. One area of over monitoring can be in cardiac telemetry. (*Circulation*. 2017;CIR.0000000000000527, originally published October 3, 2017) Having subject matter experts to help identify the clinical criteria for continuous monitoring is important in order to create clinical practice guidelines and order sets so that the right level of monitoring is achieved for each patient.

Note: The AAMI Foundation promotes the continuous monitoring of patients on parenteral opioids (www.aami.org/opioids).
3. Ensure that staff have the proper orientation to the effort and that they have available the appropriate type of sensor technology to best manage the patients.
4. Gather data to determine baseline alarm numbers and types of SpO₂ alarms to use as markers to demonstrate improvements as changes are effected.

FOCUS GROUPS

One method to use in data gathering is to bring together healthcare organization clinicians in focus groups. Below are some questions you can pose to your focus groups.

1. Is there a capability to extract alarm logs and use these data to report findings? Does the vendor provide reports that you can leverage for your assessment of alarms?
2. Is there an order set for any patient who is to be monitored with pulse oximetry? Does the order define the use of intermittent and and/or continuous monitoring? If continuous SpO₂ monitoring is available, there may be a difference between when to call a provider (MD, Licensed Independent Practitioner (LIP)) or a change in SpO₂ and when alarms occur. Staff, including MD, LIPs, need to be educated.
3. Are there areas of the healthcare organization where pulse oximetry is considered a standard of care and no order is required (such as critical care, perioperative areas, opioid administration)?
4. Are there clinical indications that support individualized alarm priorities and and/or alarm defaults based on patient condition or diagnosis? For example, if a patient is known to have an unstable airway or is in acute respiratory failure, consider setting these alarms at a high acuity level.
5. Are there a subset of patients that can be identified that are at higher risk for complications and would benefit from from SpO₂ monitoring (i.e., risk stratification)?
6. Discuss alarm default baseline levels based on the care area and cohort of patients. (Evaluate certain patient conditions where customized settings can safely be made to reduce erroneous alarms).

SECTION

III

HOW WELL DO YOU KNOW YOUR SPO₂ ALARMS?

Highlights of this section

- Introduction to the measurement of pulse oximetry
- Alarms that are generated
 - Machine alarms
 - Patient alarms
- Desaturations
- Sharp Declines
- Slow/Steady Desaturations
- Trended Data
- Duration of Alarms
- Causes/Considerations/Expected Values
 - Chronic Conditions
 - Obesity
 - Acute Conditions
- Monitoring
 - Spot Check (intermittent)
 - Continuous Monitoring
- Limitations/Contra indication/Hazards
 - Limitations and Inaccurate Readings
 - Contraindications
 - Hazards/Complications
 - Infection Control
 - Conclusions

INTRODUCTION

Measuring SaO₂ requires arterial (oxygenated) blood to be drawn from the patient via arterial puncture or through an arterial line where the blood sample is then run through a blood gas analyzer. While this procedure is the most accurate way to measure oxygen saturation, it does have its drawbacks. Most notable are:

- Discomfort for the patient with blood drawn via arterial puncture
- Hematoma as a result of arterial puncture
- Timing. Takes time to transport blood and run sample via blood gas analyzer
- Cost. Blood gas analyzers are expensive machines, which require frequent calibrations and calibration gases.

While blood gas analyzers are the most accurate way to measure a patient's oxygen saturation, pulse oximetry is a non-invasive, painless, cost-effective, timely monitoring tool to measure a patient's peripheral oxygen saturation (SpO₂) and has a very close correlation to its more invasive counterpart (SaO₂), thus making it a valuable tool for healthcare providers and patients. In otherwise healthy subjects, pulse oximetry readings commonly have a mean difference (bias) of < 2% and a standard deviation of +/- 3% when SaO₂ is > 90%.²

Pulse oximetry is measured by placing a small probe on a "thin" or narrow body part, typically a finger, earlobe and in some cases even a toe or a foot (neonates and adults in induced hypothermia). These non-invasive probes measure how much of the hemoglobin in the blood is actually carrying oxygen (oxyhemoglobin) and how much hemoglobin is not (deoxyhemoglobin). Subsequently, the oxygen saturation is a percentage of how much of the hemoglobin in the blood carries oxygen.

Oxygen saturation is measured when a combination of red and infrared light is emitted from one side of the probe, travels through the finger, earlobe or toe and is captured by a light detector on the other side of the probe. According to Beer's Law, the amount of light absorbed is proportional to the concentration of the light absorbing substance. Oxyhemoglobin absorbs infrared light while deoxyhemoglobin absorbs red light, thus oxygen saturation is measured by calculating the difference between how much red and infrared light is delivered by the probe vs. how much was captured by the light detector. Hence, high amounts of oxyhemoglobin circulating through the finger, earlobe or toe, yields high absorption of the infrared light and thus a high oxygen saturation. High amounts of deoxyhemoglobin in the blood yield high absorption of red light and subsequently a low pulse oximetry reading.

Like all monitoring tools used in the acute hospital environment, the decision to continuously monitor SpO₂ vs. intermittent monitoring should be at the discretion of the LIP and should consider the following:

- Physical findings, appearance and presentation of the patient
- Documented history of cardiopulmonary lung disease (or lack thereof)
- Acute condition
- Use of oxygen

ALARMS

This section will discuss the differences between machine alarms and patient alarms. In addition, basic information will be given on how to address both types of alarms.

Machine Alarms

These are alarms that are typically associated with the pulse oximeter itself. Examples of these are: low battery alarm, patient sensor disconnects, and machine sensor disconnect. These are intended to give the clinician early warning that either monitoring has ceased to exist or soon will. These alarms are important and should be addressed in a timely manner.

Patient Alarms

These alarms are directly related to patient condition and can either serve as a nuisance, or can signify a serious life threatening condition with the patient. The alarms typically include high and low SpO₂ reading, and high and low heart rate.³

There are many factors that affect the precision of these patient alarms. Patient movement may cause artifact that will make determining whether or not these alarms are legitimate care concerns or not. These artifact alarms contribute to alarm fatigue and much work is being done to avoid this. Many producers of pulse oximetry technology have worked hard to determine the best way of reducing “nuisance” alarms caused by artifact. These changes in internal algorithms often include “averaging” of physiologic readings and “delay” in reporting short-lived alarms. Although this may seem like a reasonable approach to these nuisance alarms, overall they may reduce the sensitivity and correlation with “real” physiologic changes with the patient.

Other influences that may affect the accuracy and usefulness of pulse oximetry will be discussed later in this document.

Addressing pulse oximetry alarms

Seemingly intuitive, the first step in addressing any pulse oximetry alarm is to evaluate the patient and look for distress. High and low heart rate alarms should be correlated with patient condition. As an example a high heart rate could be associated with respiratory distress, pain, anxiety, or artifact. A low heart rate could be associated with hypoxemia, airway obstruction or the result of narcotics or other pharmacological agents. At any rate, these acute changes of heart rate should be considered real until corroborated with checking the pulse on a second site.

It is important to remember that the use of supplemental oxygen with a patient on continuous pulse oximetry will DELAY the point in time where the pulse oximeter will respond to changes in patient condition. As an example, a patient who is apneic may not show signs of this change on the pulse oximeter for several minutes. This will depend on the patient’s underlying pathophysiologic condition and severity of illness.³

Addressing high and low SpO₂ alarms should be done in the same fashion. Patient distress should be evaluated and then etiologies of hypoxemia or hyperoxemia should be sought. Once the patient is believed to be hypoxemic, consult with LIP to discuss supplemental oxygen. As an example, a chronic COPD patient may have a lower targeted SpO₂ goal. Patients with a dyshemoglobinemia may have a higher than normal target range.

If the issue is believed to be equipment malfunction, then the sensor and/or pulse oximeter should be replaced. If changes in perfusion, artifact, or increased ambient light are thought to be at fault, then steps to evaluate these should be taken. As an example, switching sensor placement or eliminating the excessive ambient light should be done.⁴⁻⁵

ALARM FATIGUE & INTERPRETATION OF ALARM DATA

Alarm Fatigue

According to The Joint Commission, clinical alarms not properly managed by healthcare providers can compromise patient safety. As such, 2014 NPSG.06.01.01 was created to address alarm fatigue and other adverse outcomes associated with clinical alarms.⁶ In response to this and to better prepare and educate the healthcare community to these challenges, the AAMI Foundation developed a Clinical Alarm Management Compendium.⁷ According to AAMI, alarm noise, which creates an unpleasant environment for patients, families, and staff may lead to:

- Desensitization to “white noise” as staff become accustomed to the sound
- Distraction resulting in errors
- Delayed response time
- Alarm conditions perceived as “nuisance alarms”

The impact “noise” has on healthcare is significant. Effects of excessive noise on patients/families and healthcare staff are as follows:

Patient & Families	Healthcare Staff
Sleep disturbances	↑↑ Occupational stress
Delirium	↓↓ Staff performance, work satisfaction, health outcomes
↑↑ Blood pressure	Delays in recognition and response to medical alarms
Negative effects on immune system	Affects oral communication and increases errors
Slower healing and recovery process	
Increased length of stay	
Impact on patient satisfaction surveys	

Desaturations

As discussed previously, when artifact is present or when pulse oximetry alarms are not set appropriately they can often lead to constant and/or nuisance alarm conditions that contribute to alarm fatigue. With that said, these alarms must be set with the patient’s current clinical condition in mind. It is with this hope that by having alarms set appropriately, healthcare providers are only alerted to conditions that require intervention not false alarms that only serve to be a nuisance or for conditions that do not necessitate an intervention.

Currently, there is little evidence-based literature published on pulse oximetry alarm settings. Every patient is unique and requires their pulse oximetry alarm settings to be customized to their current condition and physiologic needs. Failure to properly set alarms will likely lead to constant conditions in which the alarm will be triggered. When this happens, alarm fatigue can set in creating either a false sense of security for the clinician or complete disregard for the alarm, thus creating an unsafe environment for the patient.

CHANGES IN PATIENT CONDITION

This section is meant to serve as a guide for clinicians to better understanding what the alarm is telling them in differing scenarios (sharp declines vs. slow steady declines) as well as the importance of monitoring desaturation trends and duration of alarms.

Sharp Declines

There are number of potential clinical reasons that lead to a sharp decline or “rapid” oxygen desaturation. In these scenarios when there is a real and acute change in the patient’s oxygenation status, it is likely the clinician will notice acute changes in the patient’s appearance. These include, but are not limited to the following.⁸⁻⁹

ANESTHESIA	BEHAVIORAL CHANGES
LIGHT HEADEDNESS	SWEATING
ATAXIA	PAPILLOEDEMA
FATIGUE	REDUCED LEVEL OF CONSCIOUSNESS SEVERE HEADACHES
CONFUSION	
NUMBNESS	BREATHLESSNESS
DISORIENTATION	PALLOR
TINGLING OF EXTREMITIES	TACHYCARDIA
HALLUCINATIONS	CYANOSIS
NAUSEA	

Some of the more common causes of sharp or “rapid” desaturations include, but not limited to the following:

- Shortness of breath, physical activity (getting out of bed, ambulating)
- Asthma attack/bronchoconstriction
- Tachycardia (acute change in HR)
- Malpositioned pulse oximetry probe

It is imperative that the clinician is aware of the cause and effect of rapid desaturation and notes that when it does take place it could be either a real desaturation or potentially artifact. Thus, it is incumbent on clinicians to use their assessment skills to determine whether a real clinical emergency is taking place, or whether an event has taken place that has a negative impact on the accuracy of the pulse oximetry reading.

Slow/Steady Desaturations

While all desaturations should be monitored with concern, slow and steady desaturations are likely indicative of more serious conditions whose symptoms worsen over time. These include, but not limited to the following:

- Pulmonary Shunt
 - Atelectasis
 - Mucous plug
 - Pneumonia
 - Pulmonary edema
- Acute/Chronic Respiratory Failure
- Pulmonary Embolism
- Heart Attack

It is not impossible that slow desaturations over time are the result of artifact; however, trended data over a prolonged period of time are more likely to indicate a concerning clinical condition as opposed to an inaccurate pulse oximetry reading at one point in time. As such, slow desaturations should be addressed with a high degree of caution with suspicion that there is an underlying condition taking place.

In these instances, the clinician should trust their clinical judgment, assess the patient for other signs of hypoxemia and move forward in their recommendations of appropriate diagnostic testing (i.e. EKG, X-ray, CT Scan, blood gas analysis etc.).

Trended Data

For many of the reasons detailed above, capturing trends in pulse oximetry data is of great importance in the care of patients being monitored with this technology (either by continuous or intermittent monitoring). It is important to note that both intermittent and continuous saturation monitoring only provides the clinician with a singular data point at one point in time. A SpO₂ of 92% may be reflective of a safe, but less than ideal oxygen saturation; however, this singular data point means very little without a) a baseline measurement to compare it to; and b) trended data to give a numerical and graphical depiction of what has historically taken place with the patient over a defined period of time. It is through trended data that the clinician can monitor the oxygen saturation of a patient and make determinations whether or not the patient's oxygenation status has been stable over a defined period of time, whether it is improving, or whether or not it is on the decline.

Technologically advanced software in today's pulse oximeters and electronic health record platforms provide the clinician with the ability to download trended data and is an assessment all clinicians should consider when examining their patients.

Duration of Alarms

When set appropriately, and with advancements in today's technology, desaturation alarms on pulse oximeters should (in theory) only alarm when a clinical condition occurs that warrants an intervention. Thus, should the pulse oximeter alarm continuously, the clinician should take immediate action to assess the patient for signs of hypoxemia.

In the event the patient's physical findings ARE NOT suggestive of a hypoxemic condition and the pulse oximetry alarm continues, the clinician should also consider the following:

- Confirm the presence of artifact (or lack thereof)
- Check to ensure the pulse oximetry probe is not malpositioned
- Check for clinical conditions that could impact the limitations/accuracy of the pulse oximetry monitor (see limitations section of this document)
- Contact the LIP immediately
- Consult with LIP for an arterial blood gas to be drawn

CAUSES/CONSIDERATIONS/EXPECTED VALUES (DEFINE THRESHOLDS)

Chronic Conditions

There are chronic conditions where hypoxemia/hypoxia may be pre-existing. Consideration should be made when managing these patients. Lower thresholds may be tolerated in certain cases. Baseline conditions should be understood by the managing team so that acute or chronic changes can be recognized and dealt with. Pulse oximetry saturations of 88-90% are often considered to be baseline when chronic hypoxemia exists in the 50-60 mmHg range. Although monitoring should be customized according to chronic “irreversible” conditions, acute hypoxemia should be managed the same way in all patients. Some of these chronic conditions are listed below.

- Chronic Obstructive Pulmonary Disease (COPD)
- Cystic Fibrosis
- Pulmonary Hypertension
- Pulmonary Fibrosis
- Asthma
- Congestive Heart Failure (CHF)

Obesity

Obesity can precipitate acute and chronic hypoventilation and compressive atelectasis. These in turn may cause hypoxemia. This is especially true in those patients who are being managed with sedation and or analgesia. Continuous monitoring should be initiated in patients that are obese and have risk factors for any of the above.

Acute Conditions

Acute causes of hypoxemia and hypoxia should be monitored closely for changes in gas exchange. It is important to avoid both profound hypoxemia and the use of high levels of oxygen concentration. It is typically accepted that one should maintain oxygenation at a point on the oxy-dissociation curve that leaves some room for slight deterioration before reaching the steep portion of the curve where quick decompensation occurs. This is usually somewhere between 90-94% depending on other factors such as acidemia, core temperature and hemoglobin levels.

- Pneumonia
- Acute Respiratory Distress Syndrome (ARDS)
- Multi-System Organ Failure (MSOF)
- Asthma
- Congestive Heart Failure (CHF)

Monitoring

Monitoring can be achieved by either checking the patients SpO₂ intermittently (spot check) or through continuous monitoring. The patient's condition and risk for complications or decompensation should dictate the appropriate type of action. Procedure type if any should as well.

Spot Check (Intermittent)

In many areas it has become standard to “spot-check” a patient's pulse oximetry level as often as traditional vital signs. Although strong evidence does not support this practice, it may make good clinical sense in some cases:

- Patients who are requiring low level supplemental oxygen should be spot-checked to assist in titration and discontinuation.
- Patients who are exhibiting signs of hypoxia should be spot checked as well, as a screening tool to assess for improving oxygenation in acute or urgent scenarios.
- May require an LIP order.

Continuous Monitoring

Patients who are at high risk of developing worsening oxygenation should have continuous pulse oximetry monitoring. These include but are not necessarily limited to:

- Patients receiving Patient Controlled Analgesia (PCA)
- Patients who are being managed on high levels of supplemental oxygen
- Patients who are receiving invasive or non-invasive mechanical ventilation
- Patients who are known or at risk of having obstructive sleep apnea (OSA)
- Peri-operative management
- Patients receiving parenteral opioids

Reminder: As previously mentioned, it is important to remember that the use of supplemental oxygen with a patient on continuous pulse oximetry will DELAY the point in time where the pulse oximeter will respond to changes in patient condition. As an example, a patient who is apneic may not show signs of this change on the pulse oximeter for several minutes. This will depend on the patient's underlying pathophysiologic condition and severity of illness.³

LIMITATIONS/CONTRAINDICATIONS/HAZARDS & COMPLICATIONS/INFECTION CONTROL

Limitations & Inaccurate Readings¹⁰

There are several limitations with pulse oximetry technology that could alter the accuracy of the device and potentially cause harm to the patient. These limitations are found in the table below.

Error Source	Effects on SpO ₂	Response
Hypotension/"Thready" Pulse, Anemia	Possible loss of signal	Correct underlying problem (e.g., give fluid challenge, lighten anesthesia), vasopressors
Vasoconstriction	Possible loss of signal, reduction of SpO ₂	Change to more central site
Hypothermia	Possible loss of signal, reduction of SpO ₂	Keep patient and extremities warm
Shivering/Movement/Muscle Twitching	Changes in pulse size, possible loss of signal	Warm and/or sedate patient
Carboxyhemoglobinemia	Falsely high SpO ₂ reading	Increase ventilation, eliminate rebreathing
Methemoglobinemia	Falsely low SpO ₂ readings approaching 85%	Administer methylene blue
Venous Pulsations	Falsely low SpO ₂ readings	Change site
Blood Pressure Cuff on Monitored Arm	Loss of signal decreases SpO ₂	Change site
Arterial Lines on Monitored Arm	Loss of signal decreases SpO ₂	Avoid use of arteries in monitored arm
Intense Bright Light (eg. Fiberoptic Fluorescent Lights)	Lower SpO ₂ readings	Avoid exposure of photodiode to light
Fingernail Polish/Press-on Nails*	Loss of signal decreases SpO ₂	Clean fingernail with acetone. Remove press-on nail. Change site
Malpositioned Probe Placement*	Loss of signal decreases SpO ₂	Reposition probe placement
Calloused Skin*	Loss of signal decreases SpO ₂	Change site. Consider ear probe
Presence of Intravenous Dyes*	Falsely low SpO ₂ readings	Monitor oxygenation via ABG until dyes are flushed from system

Source: Mardirossian G., Schnieder R.E. *Limitations of pulse oximetry*. Anesth Prog. 1992; 39(6): 194-196.

* Additional error sources not found from original source

Contraindications¹¹

The only known relative contraindication for the use of pulse oximetry is the presence of an ongoing need for measurement of pH, PaCO₂, total hemoglobin, and abnormal hemoglobins.

Hazards/Complications¹¹

Pulse oximetry is considered a safe procedure, but because of device limitations, false-negative results for hypoxemia and/or false-positive results for normoxemia or hyperoxemia may lead to inappropriate treatment of the patient. In addition, tissue injury may occur at the measuring site as a result of probe misuse (e.g., pressure sores from prolonged application or burns from the substitution of incompatible probes between instruments).

Infection Control¹¹

No special precautions are necessary, but Universal Precautions (as described by the Centers for Disease Control) are recommended. If the device probe is intended for multiple patient uses, the probe should be cleaned between patient applications according to manufacturer recommendations. The external portion of the monitor should be cleaned according to manufacturer's recommendations whenever the device remains in a patient's room for prolonged periods, when soiled, or when it has come in contact with potentially transmissible organisms.

Conclusion

Pulse oximetry is an affordable, accurate, non-invasive means to monitor a patient's oxygenation status; however, this tool is only as effective as the clinician who is using it. Thus, it is imperative that the clinician/operator of this technology fully understands its functionality and operation, clinical indications for use, pathophysiology, and disease processes that contribute to hypoxemic conditions. In addition, clinicians should also know and understand the limitations of this device and appropriate interventions for addressing these limitations both with the device as well as the patient.

It is important to note that while pulse oximetry is an effective and accurate means by which to monitor a patient's oxygenation status, it is not THE most effective means by which to do so. The standard to do so is through arterial blood gas (ABG) analysis. Pulse oximetry measurements should be correlated with ABG results to verify baseline accuracy of the device and depending upon the physical presentation of the patient, may require routine correlations for verification of accuracy. Most importantly, it is incumbent on the clinician to trust their assessment skills and what they see as opposed to blind trust from the data provided to them in the form of numbers from a machine.

Section III References

¹ Nickerson BG, Sarkisian C, Tremper KK. Bias and precision of pulse oximeters and arterial oximeters. *Chest*. 1988;93:515–517.

² Morris RW, Nairn M, Torda TA. A comparison of fifteen pulse oximeters. Part I: a clinical comparison; Part II: a test of performance under conditions of poor perfusion. *Anaesth Intensive Care*. 1989;17:62–82.

³ Cacho, G., et al. "Capnography is superior to pulse oximetry for the detection of respiratory depression during colonoscopy." *Revista Espanola de Enfermedades Digestivas* 102.2 (2010): 86.

⁴ Welch, James. "An evidence-based approach to reduce nuisance alarms and alarm fatigue." *Biomedical Instrumentation & Technology* 45.s1 (2011): 46-52.

⁵ Roth, Dominik, et al. "Accuracy of noninvasive multiwave pulse oximetry compared with carboxyhemoglobin from blood gas analysis in unselected emergency department patients." *Annals of Emergency Medicine* 58.1 (2011): 74-79.

⁶ The Joint Commission. *The Joint Commission Announces 2014 National Patient Safety Goal* (June, 2013). Retrieved from http://www.jointcommission.org/assets/1/18/jcp0713_announce_new_nspg.pdf.

⁷ AAMI Foundation. *Clinical Alarm Management Compendium*. (<http://www.aami.org/alarmcompendium>).

⁸ Robinson Grace; Strading John; West Sophie. (2009). *Oxford Handbook of Respiratory Medicine*. Oxford University Press. p. 880. ISBN 0199545162.

⁹ Illingworth, Robin; Graham, Colin; Hogg, Kerstin (2012). *Oxford Handbook of Emergency Medicine*. Oxford University Press. p. 768. ISBN 0199589569.

¹⁰ Mardirossian G., Schnieder R.E. *Limitations of pulse oximetry*. *Anesth Prog*. 1992; 39(6): 194-196.

¹¹ AARC Clinical Practice Guideline. Pulse Oximetry. *Respir Care* 1992; 37(8):891-897.

HOW DO SPO₂ ALARMS VARY BY VENDOR?

Multiparameter monitors (MPM) contain pulse oximetry technologies that are either made by the original equipment manufacturer (OEM) or companies that provide modules to the OEM. Generally, these pulse oximetry technologies frequently differ on 3 key factors that influence alarm management: 1) signal processing techniques, 2) alarm delays, and 3) algorithms employed (including averaging of the signal).

One frequently encountered challenge using these pulse oximeters is that the configurable settings from manufacturers are not altered from the defaults to meet institution-specific needs. This is particularly the case with default alarm settings and algorithmic features.

A second major challenge is that oxygen saturation is known to be a lagging clinical indicator¹. New pulse oximeters have looked to solve this through modularity and thus contain the capability to incorporate additional parameters beyond pulse rate and oxygen saturation that may be useful for subsets of patients.

Finally, connectivity (i.e., electronically capturing the data from the pulse oximeter in the electronic health record or other remote sites/systems) has traditionally been a challenge for pulse oximetry. The information monitored and tracked at the bedside is often needed by clinicians in other areas of the healthcare organization, or outside the healthcare organization altogether. Newer MPMs that include pulse oximetry bedside monitors are frequently made available with wireless capability, the ability to connect with a central monitoring station, and informatics managers that allow clinicians to view information remotely.

WHAT DO VENDORS KNOW THAT THEY WANT CLINICIANS AT THE BEDSIDE TO KNOW?

Alarm management and signal processing solutions should be created with the consideration in mind that SpO₂ alarms provide clinically relevant and technically important information to clinicians. Therefore, the goal is to engage with bedside clinicians and healthcare organizations to create a comprehensive approach to alarm management that entails generating accurate data at the bedside, intelligently processing those data through advanced signal processing techniques and escalating information to clinicians only when action is required.

Setting alarm thresholds “too tight” and failing to adjust alarm settings to individual patient needs are common causes of alarm fatigue. Vendors as well as the AAMI Foundation coalition alarm teams want to emphasize that the default settings provided by the manufacturer are adjustable and tailoring these default alarm settings specifically can help alleviate this problem.

In addition to alarm settings, we want clinicians to be aware of the importance of proper sensor selection and application. Sensors are developed and tested for specific body weight ranges and anatomical sites, so ensuring a patient meets the specifications for the sensor being used will help ensure its performance and ultimately reduce non-actionable clinical and technical alarms.

Sensor options are available for body sites other than the traditional finger sensor, including the forehead and ear. Finally, no matter the sensor used, site preparation and proper application of the sensor, per manufacturer's guidelines, are also critical factors for signal acquisition.

SpO₂ manufacturers provide technology features to reduce the incidence of non-actionable alarms while preserving actionable alarms. These technologies can be managed by customizing these settings that may have a significant impact on reducing alarm burden associated with SpO₂ monitoring. The configuration of the alarm defaults can be changed to customize them to the specific needs of the patient (i.e., COPD patient, OSA patient, etc.). However, there is a lack of science on what the proper configuration settings are for each patient population and therefore the technologies are not used to their fullest utility. It is recommended that clinicians collaborate with their SpO₂ manufacturers to understand the configurations that are available with their technologies and the appropriate settings for the patient population. In addition, white papers and research articles are available to assist healthcare organizations to properly configure the SpO₂ technologies.²

A large source of SpO₂ alarm burden is attributed to technical errors caused by mismanagement of SpO₂ sensors and cables. The following are examples of workflows that contribute to SpO₂ technical errors and recommendations for mitigating the alarms.

- Improper placement of SpO₂ sensors may cause motion artifact and poor signal quality. Healthcare organizations may define protocols to periodically check sensor placement and signal quality to ensure accurate measurement.
- Disconnection of SpO₂ sensor when the patient is being transferred causes SpO₂ disconnection technical alarm notification. SpO₂ devices and patient monitors typically support a “smart” alarm state that disables SpO₂ technical alarms while the SpO₂ sensor is being removed from the patient.
- SpO₂ sensors that have been removed from the patient but remain connected to the SpO₂ device or patient monitor may acquire ambient light that causes inappropriate SpO₂ measurements and

technical error messages. SpO₂ sensors and cables need to be properly disconnected and stored during the process of turning over the patient’s bed.

- Core temperature can influence peripheral readings (controlled hypothermia for example) so consideration must be given to select a sensor type and site that will provide accurate readings under these conditions.
- Complementary (or competing) alarm settings must also be considered. When evaluating the alarm setting for SpO₂ low pulse rate, consider the HR low alarm level setting. If these differ, there could be instances of competing alarms.
- Alarms that occur utilizing SpO₂ monitoring typically are non-actionable as evidenced by the histogram below. These alarms constitute the high majority of alarms that do not fall under the actionable category of alarm response. The typical issue associated with these might be where the limits are set.

% of Time

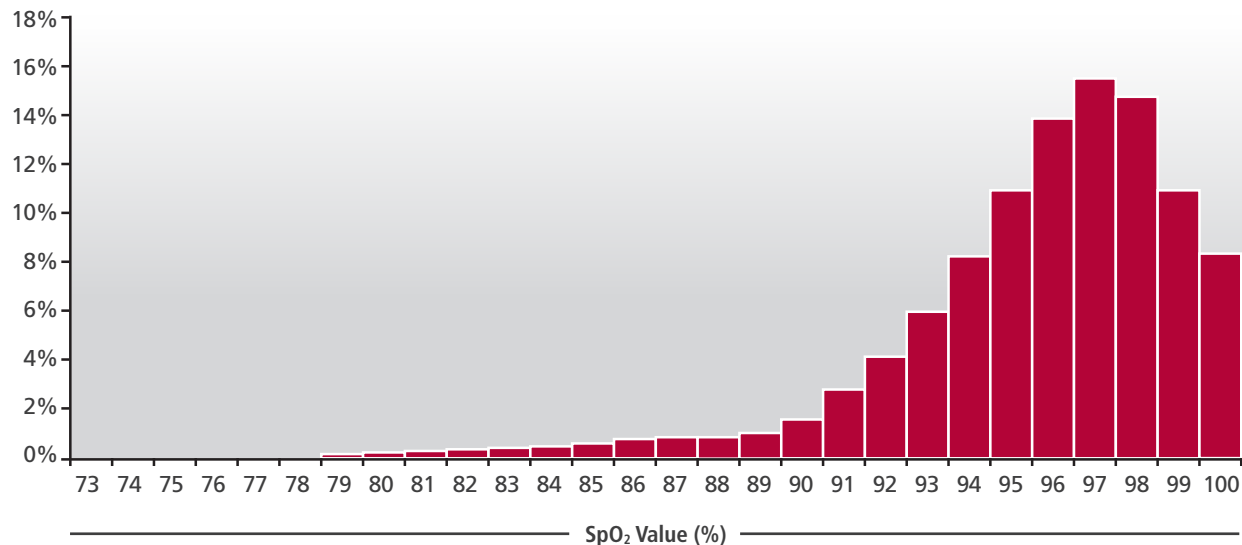


FIGURE 1. Frequency of SpO₂ values in post-surgical patients. Values under 90% occurred 4.4% of the time. However, very few of these alarms below 90% were actionable.

Courtesy, J. Welch, An evidence-based approach to reduce nuisance alarms and alarm fatigue. *AAMI Horizons*, 2011; 46-52.

Section IV References

¹ DeMeulenaere, Susan. "Pulse oximetry: uses and limitations." *The Journal for Nurse Practitioners* 3.5 (2007): 312-317.

² Medtronic. Covidien Products. Retrieved. (<http://www.medtronic.com/covidien/en-us/products/pulse-oximetry/nellcor-spo2-adhesive-sensors.html>)

HOW DO YOU GET THE DATA YOU NEED TO REDUCE FALSE AND NONACTIONABLE SPO₂ ALARM SIGNALS?

NOTE: Much of this section has been taken from a paper issued from the AAMI Foundation's National Coalition for Alarm Management Safety, and it has been customized to be specific to SpO₂ alarm signals (with permission from the AAMI Foundation). However, it is highly recommended that this referenced paper be read in its entirety, as it will assist organizations in improving how to obtain data and manage all alarm signals related to the numerous patient physiological parameters monitored by healthcare organizations.¹

Data are needed to determine which SpO₂ alarms, (technical versus patient generated) in relation to specific patient populations and hospital units, are causing the most false or nonactionable alarms. This knowledge is required before determining which SpO₂ alarm management strategies will work best across the organization or in a particular unit, (strategies such as changing the SpO₂ alarm default parameter setting across the organization, teaching clinicians how to further customize the settings based on individual patient physiological realities, incorporating alarm delays, employing middleware to assist in triaging alarm signals, etc.—please see Section IX for more information about strategies to reduce false and nonactionable SpO₂ alarm signals). Clinical improvements can be made only after a baseline alarm assessment has been established. Additionally, optimizing SpO₂ alarm signals requires the development of repeatable processes; otherwise, solutions may not translate to other clinical care areas.²

Therefore, to make a meaningful reduction in SpO₂ alarm signals, data should be collected to document baseline alarm conditions in the unit-care environments where SpO₂ measurements are employed. Baseline data to be collected include the current default parameter settings, frequency of alarm customization of default parameter settings, criticality of the alarm conditions, and number and type of alarms per patient per day. Using alarms per bed per day based on the total bed count (i.e., monitored and unmonitored) can be a problem in that beds are not always monitored; therefore, a metric based on monitored bed count per day is preferable.

CREATING THE DATA REPORT

How does the hospital alarm management committee collect this baseline data to determine which of the previously described types of SpO₂ alarm signals (false and nonactionable) exist in the facility and specifically in each unit? This can only be done by intensive tracking and trending of the data. The data collected should be meaningful and assist with achieving measurable clinical outcomes that will be of use to the stakeholders in the organization and positively affect patient care.

Summary reports. Typically, the most useful information to be collected about SpO₂ alarms for the nurse managers and the alarm committee may include:

- Alarm descriptions (what caused the alarm—technical alarm or patient-related alarm)
- Number of above alarms/patient/day by alarm description
- Number of technical and patient-generated alarms by nurse in charge of the patient (Time of day and shift)
- Number and type of alarms by department/unit
- Number and type of distribution of alarms by individual patient
- Average time: alarm duration and time to response for each type of alarm
- Number of alarm limit customization changes (totals and averages) by bed

METHODS FOR ACQUIRING ALARM DATA

Getting the baseline SpO₂ data to inform the items described in the summary reports, above, out of the physiological monitors can be challenging, especially if the monitors are more than 8 to 10 years old. Older monitors often may not have the capability to save data that can be easily downloaded to create the reports. Newer monitors typically have the capability to store alarm data that can be exported to spreadsheets to create alarm reports, and many of the newest monitors have software that can



directly generate alarm reports, which sometimes can be customized for the hospital's individual needs. Discussing the current monitors' capabilities for downloading SpO₂ alarm data and creating reports is critically important. Retrieval of this alarm data varies according to the model and functionality of specific monitors. The hospital should confer with the manufacturer on available options and select the one that fits best according to internal resources.

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

The vendor may have a software upgrade that is compatible with the hospital's current model of monitor that can be installed to produce ongoing SpO₂ alarm data/reports (vendors typically will charge for the software upgrade), or the hospital may decide to purchase new monitors with viable report capabilities. When hospitals negotiate contract renewals with vendors or purchase new physiologic monitors, it is recommended that usable and meaningful data reports be included in the contract, as well as how often the vendor can provide the reports. When purchasing a new software package to create reports or when purchasing new monitors, it is important for hospitals to ask the vendor what level of customization can be provided in the alarm reports and how well the canned or customizable reports meet the predetermined stakeholder needs.

In addition, the hospital may want to consider asking the vendor the following questions about the new software or monitors: How often can SpO₂ alarm signal reports be generated? At what intervals can the reports be generated? Can hospital staff run the reports? Are the reports finalized and presentable with meaningful analysis, allowing for a clinically relevant summary of the findings?

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

A third option is for the hospital healthcare technology management (HTM) and information technology (IT) departments to export the SpO₂ alarm signal data from the device server and create reports. This is labor intensive. Hospitals might consider having their monitor or middleware vendor train HTM staff to be able to obtain data reports. Depending on the size of the organization, the task of data extraction may require more or less manpower.

When hospitals do not have the resources to obtain alarm data from monitors, a fourth option would be to use low-tech methods for obtaining useful data. For example, the hospital may survey nurses in targeted units to determine how often they experience false and nonactionable SpO₂ alarm signals. Alternatively, they may manually record SpO₂ alarm-related information (e.g., number of alarm signals, duration of the alarm signals, most common types of alarm conditions, patient alarm conditions versus technical alarm conditions, clinician response time to

alarms) during unit observations and rounding. It can be helpful to meet with nurse managers and unit nurses for a daily huddle to discuss specific alarm management problems that occurred during the previous shift.³

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

IMPROVING THE ALARM MANAGEMENT PROCESS

Armed with the data collected, decisions can be made regarding which SpO₂ alarms to address first, how best to reduce the number of false and nonactionable alarms, and which unit to select to pilot the changes before rolling out to other areas of the organization. To date, no

national standards describe SpO₂ alarm default parameter settings. Multidisciplinary alarm management teams should look for opportunities to improve SpO₂ alarm signal management and reduce the likelihood of alarm fatigue by basing changes on their specific situations and by using the data from the SpO₂ alarm signal reports to drive meaningful change. Study the alarm report data (gleaned by the methods described in the previous section) to determine those alarms that are “bad actors” and where substantial improvement can be obtained by making small but meaningful changes.^{4,5} (See also Section IX of this toolkit)

Section V References

¹ Cosper, et al., **Improving Clinical Alarm Management: Guidance and Strategies**. *Biomed Instrum Technol*. 2017;51(2) 109-115 http://s3.amazonaws.com/rdcms-aami/files/production/public/FileDownloads/BIT/2017_BIT_MA_ClinicalAlarmManagement.pdf.

Welch J, et al., **Framework for Alarm Management Process Maturity**. *Biomed Instrum Technol*. 2016;50(3) 165-179. http://s3.amazonaws.com/rdcms-aami/files/production/public/Libraries/Alarms/2016_BIT_MJ_AlarmFramework.pdf

² <https://www.aami.org/PatientSafety/content.aspx?ItemNumber=1494&navItemNumber=3088> Scroll to: Papers Expanding on Alarm Compendium Recommendations; Framework for Alarm Management Process Maturity BI&T May/June 2016 Accessed January 31, 2018.

³ **AAMI Foundation**. *Fighting Alarm Fatigue with Data-Driven Interventions: The NCH Healthcare Device Eco-System Experience*. Accessed January 31, 2018.

AAMI Foundation. *Safety Innovations Series*. Available at: http://s3.amazonaws.com/rdcms-aami/files/production/public/FileDownloads/Foundation/SafetyInnovation/2016_SI_NCH_Fighting_Alarm_Fatigue.pdf.

⁴ **AAMI Foundation**. *Clinical Alarm Management Compendium*. Available at: http://s3.amazonaws.com/rdcms-aami/files/production/public/FileDownloads/Foundation/Reports/Alarm_Compendium_2015.pdf. Accessed January 31, 2018.

⁵ Cvach M. **Monitor Alarm Fatigue: An Integrative Review**. *Biomed Instrum Technol*. 2012;46(4):268–77. This is available online: http://s3.amazonaws.com/rdcms-aami/files/production/public/FileDownloads/BIT/JA_alarm_fatigue.pdf.

HOW DO YOU RUN A PILOT TO EVALUATE YOUR PROPOSED INTERVENTIONS?

The following information is based on the process and successful alarm reduction pilot study conducted at Boston Medical Center.

CREATE GOALS

Organizations should ask; what will the completion of the pilot result in? Are a set of metrics (e.g., order sets, number of patients on pulse oximetry that met the criteria for continuous monitoring, etc.) that allows the team to make informed decisions on changes to alarm settings identified? By making these changes are there any adverse patient outcomes (e.g., unexpected transfer to ICU, etc.)?

SELECTING A PILOT AREA

The alarm governance team will require input from all user areas and stakeholders and will need to prioritize which areas will benefit most from a reduction of nonactionable clinically insignificant SpO₂ alarms. The chosen pilot area requires strong local nursing and clinical leadership and a willingness to champion change management and recognize potential harm to patients. The primary purpose of the pilot area is to develop non-actionable alarm reduction strategies and processes. The staff and leadership must define why the current environment is unacceptable and agree to explore opportunities to safely improve the environment related to alarm noise. Once a pilot area is identified, the governance committee can develop a plan with the clinical staff. The pilot project is an opportunity to develop repeatable processes and actions that are transferable to other clinical use areas.

SELECT TEAMS

After selecting the pilot unit, evaluate the clinical services that admit to the floor and those relevant departments that treat on the floor and to ensure there is a diverse membership to address pulse oximetry alarms. Included in this is the wide variety of medical and surgical services,

nursing, anesthesia, biomedical engineering [HTM], respiratory therapists, physical and occupational therapies to frame an overarching pilot strategy. The following are two examples of considerations related to the construct of the team:

1) Respiratory therapists are excellent resources for the bedside clinician to provide interventions, e.g., alternate probe placement and interpretation of the data and, 2) From a practical use perspective, how do the devices work for physical and/or occupational therapists when they are performing the therapies on the patient? (e.g., workflow).

IDENTIFY SPO₂ ALARMS

The team must identify clinically insignificant alarms that contribute the most to alarm fatigue. This can be done by extracting the alarm data directly from the device, working with the medical device vendor to extract alarm data stored in the device or creating a survey tool to gain insights from the staff.

EDUCATION

The following information on educating staff is provided courtesy of Boston Medical Center (BMC)

PULSE OXIMETRY ADULT INPATIENT UNITS SKILL LEVEL

Licensed Independent Practitioner (MD, NP, PA), RN, RT (Respiratory Therapist), PT, OT, SLP (Speech Language Pathologist)

CLINICAL INDICATIONS

1. The following are indications for Continuous Pulse Oximetry at BMC
 - a. Acute Respiratory Failure
 - b. High Flow requirements
 - c. FiO₂ Requirement \geq 50%
 - d. Acute BIPAP or CPAP Requirement
 - e. Critical or unstable airway
 - f. Obstructive sleep apnea or morbidly obese patients receiving analgesia at a dose likely to induce respiratory depression.
 - g. Inter or intra-facility transport of unstable patients
 - h. Specific order sets requirement or order by MD/LIP provider

CLINICAL GUIDELINES

1. Intermittent pulse oximetry with routine vital signs is standard of care for all adult inpatients at BMC and an order is not required. Pulse oximetry spot checks do not require an order and are at discretion of clinicians.
2. Continuous pulse oximetry requires an order for its use on all adult medical surgical inpatient units except Critical Care and the Post Anesthesia Care Unit [PACU].
3. SpO₂ low default value for patients on continuous pulse oximetry will be 88% unless otherwise specified by Order Sets or by LIP order.
4. Immediate LIP notification must occur for the following
 - a. Consistent SpO₂ of \leq than 88% or \leq than otherwise ordered value
 - b. SpO₂ drop of 5 points or more from prior value for example 95% to 90%
 - c. While notifying the MD/ LIP, RN may titrate FiO₂ to obtain SpO₂ \geq 88% or ordered goal
5. An RN or RT may initiate continuous pulse oximetry for changes in patient's clinical condition but they must obtain an order for continuous pulse oximetry within 4 hours if continuous pulse oximetry is to be continued.
6. For a patient having true SpO₂ low crisis alarms at the default of 88% with a chronic reason for such lower SpO₂ values that the medical team has documented, two RNs or

an RN and RT may collaborate to lower SpO₂ to 85% but must obtain an order within 1 hour for this default change. Alert level for SpO₂ must remain at Crisis Level.

7. Oxygen therapy requires an order and may be titrated to an ordered targeted oxygen saturation value or SpO₂ range.

EQUIPMENT

Pulse oximetry monitoring equipment

Sensor probes

PROCEDURE

1. If using a reusable sensor, sanitize the sensor prior to use. Assess the patient's skin integrity prior to application. Do not apply to skin with cuts or breakdown.
2. Monitor skin site regularly for signs of any excessive pressure or blister development. If possible, routinely move sensor to alternate site.
3. Place the sensor on the index or 3rd finger making sure the eyes of the sensor are aligned across from each other and that the sensor is securely in place. If the sensor is picking up a pulse, a visual amplitude bar or a wave pattern depending on the specific machine, will be displayed and a digital pulse rate and SpO₂ shown on the monitor screen. If the sensor does not produce an accurate or consistent signal, follow troubleshooting steps. If still unable to obtain an accurate consistent waveform, consult Respiratory Therapy to assist with troubleshooting.
4. Continuous pulse oximetry the waveform is to be displayed on the central monitor.
5. When monitoring continuous pulse oximetry only without telemetry the SpO₂-R alarm level should be changed from Message to Crisis to capture HR < than 40 or >than 130.
6. Intermittent and continuous SpO₂ values are charted in the EHR when entering routine vital signs and with any significant changes in SpO₂ values. Notify MD/LIP for significant changes as defined in preceding Clinical Guideline Section.

CLINICAL INFORMATION

The pulse oximeter is a non-invasive method of measuring pulse rate and oxygen saturation. A sensor clip is most often placed on the finger but may be placed on toe, nose, or ear lobe. The sensor has two light emitting diodes (LED) which transmit light through the skin and the tissue to a photodetector. The LED and the photodetector eyes on the sensor need to be aligned with each other for accurate readings. The light absorption characteristic of oxygenated and deoxygenated hemoglobin are then computed based on the light absorption characteristics and pulse rate and oxygen saturation (abbreviated SpO₂ or SaO₂) displayed on the digital monitor.

2. To minimize poor waveforms causing false SpO₂ low crisis alarms, a 15 second delay has been programmed. A monitor safety default exists that this delay becomes 5 seconds whenever the monitor senses that an SpO₂ drops 4 % or greater below the programmed default. For a SpO₂ low default of 88%, the change to 5 second delay occurs at an SpO₂ value of 85%. Sleep apnea patients often transiently drop SpO₂s into the mid-80s overnight for periods usually <than 15 seconds which would trip this occurring. For this reason, Bariatric Surgery has chosen to lower their SpO₂ low default to 85%. By lowering the SpO₂ low default to 85% the value at which the monitor reverts to 5 second default is 82%. Until this value is reached, brief changes in SpO₂ values that are above 82% lasting < than 15 seconds, will not trip a Crisis Alarm. You may find other patients where individualizing default such as done here may be beneficial, such as patients on Flolan with significant pulmonary hypertension.
3. The oxyhemoglobin dissociation curve depicts the relationship of SpO₂ to PO₂. Under normal physiological conditions, a SpO₂ value above 95% correlates to a PO₂ value in normal range of 80-100mmHg; a SpO₂ of 90% or below reflects a PO₂ below 60mmHg
4. The pulse oximetry waveform should be visible on patient monitor to confirm accuracy of the digital SpO₂ readout. For intermittent pulse oximetry take the patient's pulse for 15 seconds and check that it is within +/- 10 beats of the monitor's HR read out. The SpO₂ is considered accurate if both manual and digitally displayed pulse rates are similar.
5. If there is question about SpO₂ accuracy an ABG or VBG should be obtained simultaneously with pulse oximetry to verify accuracy of the SpO₂ value.

MANAGING THE PILOT

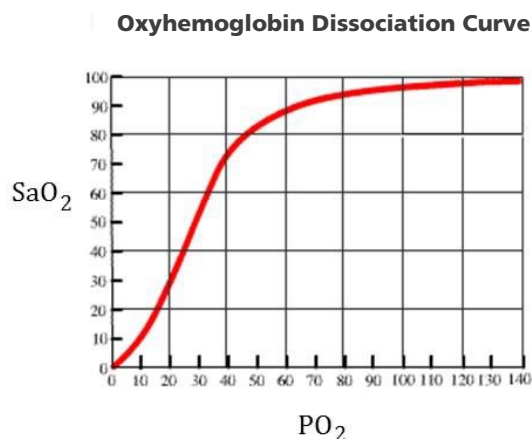
The team must be vigilant that true and actionable clinical events are not lost with each pilot phase. Staff surveys and education will help the team understand the progress of the pilot, provide feedback on additional opportunities for improvement and also make subsequent pilots go better.

Super user guide for the pilot unit

The following are guidelines for your role when you are a super user assigned to the pilot unit:

Introduce yourself to Nurse Manager and Charge Nurse and ask that after shift report that they call for a Huddle.

FIGURE 1. Oxyhemoglobin Curve. Relationship of SpO₂ to Arterial pO₂



Approximate Range of PO₂ to SpO₂

PO ₂	SpO ₂
100	97.4
90	96.5
80	94.3
70	92.7
60	89
50	83.5
40	75
30	57
20	35
10	13.5

Check in with the Super user who is leaving. They will give you a brief report on how the prior shift has gone as well as the laptop that you will use to track the pilot metrics you will be looking at during your shift.

At the Staff Huddle

Introduce yourself

Review Key Changes to Pulse Oximetry on Unit:

- That Continuous Pulse Oximetry requires an order in the EMR
- That Intermittent Pulse Oximetry with routine VS is now the standard of care for all other patients on the unit
- That both continuous and intermittent SpO₂ value are entered to flowsheet when Routine VS are entered
- That continuous pulse oximetry waveform is to be displayed as a wave on the central monitor
- Review Alarm Changes

SpO₂ low

- Now triggered by an SpO₂ of $\leq 88\%$ for 15 seconds. Remind staff that this is a PO₂ $\leq 55\text{mmHg}$
- Will now occur as CRISIS ALARM that requires immediate response by staff

SpO₂ Probe off

- Triggered by probe disconnect from patient
- Creates a SYSTEM ALARM that requires immediate response by staff
- This alarm can be avoided by remembering to Pause Alarm when patient off unit or when patient ambulatory and continuous SpO₂ monitoring is being checked by different piece of equipment such as a spot check device.
- If continuous not required obtain order to discontinue order

Finally, review Indications for Continuous Pulse Oximetry and ask staff if there are patients who are on continuous pulse oximetry that no longer meet criteria or are there patients on intermittent who should be on continuous by criteria?

Next on the Unit

- Check Central Monitor to identify patients' who are on Continuous Pulse Oximetry
- Review these patient's orders for a continuous pulse oximetry order

- If there is no order for continuous pulse oximetry discuss with RN why the patient is on continuous pulse oximetry and if meets indication for continuous pulse ox have RN contact team to place order
- Now assess all other patients on the floor to be sure they do not meet an indication for continuous pulse oximetry.

If you find a patient who does meet indication such as a patient on FiO₂ $> 50\%$ discuss with RN and ask RN to contact team to have team place a continuous pulse oximetry order.

Throughout Shift

Your job is NOT TO ANSWER ALARMS, rather if an alarm occurs (either SpO₂ or Cardiac Rate/Rhythm Alarms), provide feedback to staff on alarm management. RN Staff own the alarms.

- Wait two minutes for staff to respond
- After two minutes if staff have not responded:
 - If between 7AM and 9PM overhead page "Low SpO₂ Rm14 Bed 1"
 - 9PM-7AM find the RN or her colleague and ask them to respond to the alarm

During the Last Four Hours of Your Shift

Review flowsheets for documentation of continuous and intermittent SpO₂ values. Were these appropriately recorded?

Look for any values $\leq 88\%$ or that had fallen 5 points from last value.

Was team provider notified by the RN?

End of Shift

Complete Pilot Metrics tracking in laptop and send as an email attachment to Task Force Co-Chairs and Nurse Manager.

Handoff laptop to next Super user or if no Super user to Resource Nurse.

SUPER USER SUPPORT TEAM

- Manager/Educator
- Resource RN
- Respiratory Therapist
- Task Force Leader – Nursing [24/7]
- Nursing Director
- Task Force Leader - Clinical Engineering [24/7]

HOW DO YOU DESIGN BEST PRACTICE ORDER SETS?

Order sets for the use of pulse oximetry help direct providers to selecting the appropriate level of monitoring for each patient. Boston Medical Center (BMC) developed orders to guide the providers through a number of prompts to ensure that they consider the patient condition and default alarm considerations for patients.

Upon opening the order for oxygen saturation, the default mode of monitoring is routine. The provider will have the option to select *continuous* after answering several prompts regarding the patient diagnosis and condition.

- *Indication for Continuous Pulse Oximetry: Drop down
 - Acute Respiratory Failure, High Flow O₂, FiO₂≥50%, Acute BIPAP or CPAP, Critical or Unstable Airway, OSA

or Suspected OSA Receiving Analgesia with potential to Induce Respiratory Depression, *Other (Which must be specified by LIP)

- * SpO₂ Lower Limit: Defaulted 88% but can be opened by LIP to adjust default 75% to 95%
- *Changes to Standard Alarms: Drop down /LIP may select more than - None, Known chronic hypoxemia may lower SpO₂ low alarm to 85% without additional orders, Continuous pulse oximetry not required when out of bed

Oxygen Saturation Accept Cancel

Priority: Routine

Frequency: Q15 Min Q1H Q2H Q4H Q8H Q Shift Per Unit Routine Continuous

Starting: Today Tomorrow At: 🕒

First Occurrence: **Today 1451**

Scheduled Times: [Hide Schedule](#)

Comments (F6): 🔍 abc 📎 🗑️ ? 👤 + 📄 ↶ ↷ 👤 📄

Indication OSA refusing CPAP and receiving narcotics

Lower default SpO2 at night to 86%

Next Required Link Order Accept Cancel

FIGURE 2. Order set screen for use of pulse oximetry

Courtesy: Boston Medical Center

** Note from the AAMI Foundation: Hospitals may want to continuously monitor all patients on parenteral opioids. (<http://www.aami.org/opioids>)*

The orders were developed after much discussion with the providers, which allowed them not only to participate in the discussion but also determine the prompts and specific patient populations where different alarm defaults would reside.

Bringing providers into the discussion helped the pilots run efficiently and effectively.

PILOTING A PULSE OXIMETRY ALARM STUDY AT BOSTON MEDICAL CENTER (BMC)

This is not prescriptive by design. The pilot case study is intended to tie the NPSG EPs to managing alarms associated with pulse oximetry.

The AAMI Foundation would like to express its sincere thanks to the staff at Boston Medical Center for their outstanding work and their willingness to share their insights.

PROBLEM STATEMENT

Define the current problem/reason for action	Following the successful implementation of the cardiac monitor alarm reduction project BMC found that there remained a significant number of alarms contributing to alarm fatigue that stemmed from SpO ₂ alarms. On further review BMC found that standard policies, procedures and order sets governing application of this technology were lacking and there was significant opportunity for improvement in application of this technology across the organization.
Discuss any potential barriers to success	Achieving interdisciplinary consensus on application of O ₂ sat monitoring technology.
Provide baseline data to support the problem statement	Currently SpO ₂ alarms constitute over 1/3rd (39%) of all audible alarms on the medical surgical units. On the step down unit, that served as the pilot unit over 1/3rd (32%) of all alarms comes from SpO ₂ alarms.

ACTIONS TO RESOLVE PROBLEM

Following upon the successful cardiac alarm pilot format used, BMC evaluated the notion of effectively reducing pulse oximetry alarms in the ten med-surg telemetry units. The important segments of a pulse oximetry pilot are listed below with some brief descriptions of important considerations. There are also some lessons learned to help provide some items that BMC encountered, which caused them to make some changes not only to the pilot but also to clinician workflow.

Assessment of current environment, utilization and technology

Assessing alarms can take many shapes and include a variety of sources of information. They include:

- Assessment of internal incident or events
- Evaluating staff feedback
- Risks with patient monitoring based on the geography of a unit and the ability of staff to see/hear alarms
- Risks associated with the ability of staff to hear and respond to actionable alarms based on the overall noise on the unit and competing alarms
- Current utilization of technology and what barriers exist with alarm settings (more in Evaluate Data Sources on next page)

- Assessment of the technology including alarm defaults, feature differences

Lessons learned: Although BMC standardized on a single vendor, there are a few different software versions that have some different features related to alarm delay and default settings. BMC created a chart of what they are, shared this with the staff on the pilot unit and governance team and also labelled the devices so that the staff could identify the versions. This came into play with the education piece of developing the pilot as well as the development of troubleshooting tip sheets. (more in create pilot go-live support)

Create governance structure

Pulse oximetry is a technology that crosses a number of clinical services with a variety of clinical requirements. Before a pilot unit is identified, it is important to identify the departments and services as these stakeholders will determine the governance structure for your alarm initiative.

Lessons learned: Including all clinical services who had admitting privileges to each pilot unit, consultative services (e.g., Pulmonary Medicine, Bariatric Surgery) as well as support services that provide care to patients such as Respiratory Care and PT/OT. Organizations should evaluate who interacts with the patients on the unit so that all stakeholders are identified.

Evaluate data sources

Data comes in many forms. Alarm data retrieved directly from the monitoring system is a great source of truth to identify the current state of alarm conditions and quantity of alerts, but there are other sources of data because not all organizations can extract these data directly from devices. The following are some examples of data retrieval:

- Get alarm data directly from the device.
- Data extracted and reported through vendor.
- Data extracted and reported through a middleware solution.
- Direct observation of staff and how they respond to alarms. How well do they respond to critical alarms? What are the other alarms and sounds that impact staff?

Manual counting of alarms, although labor intensive and generally is only for a brief period of time, will provide some insight into the typical alarms that are occurring.

Lessons learned: BMC found that with alarm sounds, the escalation of noise was evident. An example is that when teams were rounding on the unit, the volume of the voices would raise over the competing noise on the unit. This led some teams to not round on the unit so they could discuss patient management in a quieter environment.

- Manually charting a sample of alarms over several periods of time to gain some understanding of what alarms occur.
- Review alarm histories at the central monitoring system to evaluate the type and frequency of alarms for a specific period.
- Survey staff on their view of alarm noise and how it may impact their ability to provide more direct care to the patient.
- Review HCAPS data related to noise. Your patients will often provide feedback on the impact of noise during their stay.
- Survey a sample of patients as well as staff to assess their experiences with noise before, during and post pilot. Although the sample will likely not be the same, patients during each phase, some common themes may emerge. Furthermore, by speaking with them about this shows that your organization is committed to addressing the issue of alarm fatigue.

- Review rapid response, code blue and other incident data to assess if changes in care or inability to intervene in patient condition changes may have been impacted by the overall noise on the care area.

Develop statement/goals of pilot including dependencies

In order to best manage the process of managing alarms, the creation of goals and objectives is an important point to ensure that there is focus and a strategy can be created to support the process.

Anticipated Outcomes / Objectives: (must be specific and measurable)

1. Create specific policies and procedures governing application of SpO₂ monitoring across adult medical surgical and step down units at BMC
2. Achieve greater than or equal to 15% reduction in audible SpO₂ alarms across adult medical surgical and step down units
3. Reduce product expense of disposable SpO₂ probes by 20% through improved utilization.

Lessons learned: One of the things BMC learned from speaking with stakeholders, evaluating alarm data and observing staff was that all patients were on continuous pulse oximetry, many of them without an order. BMC found that the policies and procedures within the organization did not adequately identify the clinical indications for the use of continuous pulse oximetry. During their discussions with the governance team, BMC was able to identify the clinical alarm indications for those patients that should be continuously monitored versus those that could be monitored every four hours.

The result of these discussions was to create a standardized pilot policy and procedure that helped identify the clinical indications for use, the clinical guidelines for the intermittent and continuous use of the technology, a procedure utilizing the technology as well as some clinical information about the technology and the measurement.

Establish pilot unit

Creating a single pilot unit is a best practice because there is a dedicated focus on the process of the pilot and the necessary resources to help support it can be identified. If more than one unit is active, resources become diluted and there is a potential for inconsistent management of the process. There are a few considerations for identifying the pilot unit. They are:

- Select an area where there is a high volume of alarms
- Choose a unit that volunteers for participation
- Work with a unit that was surveyed and indicated that there were issues associated with alarm noise and specifics related to patient care were identified.
- Identify a unit where the HCAPS scores would benefit from an alarm pilot.
- Review rapid response, code blue and other incident data to assess if changes in care or inability to intervene in patient condition changes were identified. An important consideration for this example is to frame the pilot as an opportunity to facilitate a change to improve the environment and enhance patient safety. The senior leadership and governance team should help reinforce this so it is not seen as a “problem area” but instead as an opportunity to help improve their work environment.

Establish buy-in

Commitment to change can be a challenge, regardless of the initiative. Clinicians are constantly inundated with new processes and programs so it is incumbent upon the governance team to create a support model to ensure that the pilot has the highest chance of success. The clinical leadership and unit leadership are the drivers of this initiative but formulating a tool set for the bedside staff is critical so that the following are identified:

- Educating staff on the technology
- Educating staff on what the proposed changes are, what the impact of the changes should yield creating an opportunity for questions, comments and concerns are critical elements for success.

Establish educational program

The creation of an educational initiative to support the pilot is critical. Providing the tools to ensure that all staff is prepared to utilize the technology to its fullest capability is essential.

Create go-live support

On-site resource nurses and respiratory therapists to reinforce the use of the pulse oximetry, answer procedural questions and also reinforce proper use (continuous vs q4).

Supporting pilot

- Local Champions throughout the roll out
- Being available 24/7
- Create ability for two RNs working together to review the patient status and suggest an alarm setting change (i.e. lower or increase HR parameter or alarm level) and then obtain order from House Officer/LIP confirming their change.
- Development of a centralized site (ex.: Sharepoint™) to journal and chronicle the staff observations.
- Daily/Weekly/Monthly Tips and Huddle cards

Monitor and measure

Track and present data pre-pilot, go-live and post go-live is an important method to measure the effectiveness of change.

Can current changes be expanded house-wide? Considerations

Presenting the data to demonstrate what changes were made and the effectiveness of the changes will help frame discussions as you look to expand it beyond the pilot unit. Identifying the services that admit to subsequent evaluation units will be an important piece to factor as you look at evaluating alarm thresholds, delays and specific order sets.

Sustainability

Sustainability can be a challenge with any initiative but by reducing the overall noise on the unit, as well as creating an environment where all alarms are actionable, creates a setting where staff can have a better work experience. Should alarms start to creep up, local ownership and management of the environment is in the best position to emphasize the need to manage alarms as outlined during the pilot.



WHAT RESOURCES CAN YOU USE TO GUIDE YOU ON YOUR ALARM MANAGEMENT JOURNEY?

AAMI Foundation Clinical Alarm Management Compendium, 2014

<http://www.aami.org/alarmpendium>.

American Association of Critical-Care Nurses

<http://www.aacn.org/wd/practice/content/practicealerts/alarm-management-practice-alert.pcms?menu=practice>

National Association of Clinical Nurse Specialists

<http://www.nacns.org/html/alarm-fatigue.php>.

AAMI REFERENCES OF NON-ACTIONABLE ALARMS

Adult SpO₂

Emergency Care Research Institute, Top Ten Health Technology Hazards for 2014, *Health Device* November 2013, https://www.ecri.org/components/Pages/Alarm_Safety_Handbook.aspx Accessed 10/5/2015.

Welch, J., An evidence-based approach to reduce alarm events and alarm fatigue, *AAMI Horizons – Improving Medical Alarm Systems*, Spring 2011, pages 46-52.

Taenzer, A. et al., Impact of pulse oximetry surveillance on rescue events and intensive care unit transfers: a before-and-after concurrence study, *Anesthesiology*. 2010 Feb;112(2):282-7.

R3 Document on NPSG 06.01.01,

https://www.jointcommission.org/assets/1/18/R3_Report_Issue_5_12_2_13_Final.pdf

Welch, J., Pulse Oximetry. *BI&T* 2005 Feb/Mar: 125-130.

The Impact of Clinical Alarms on Patient Safety: A Report from the American College of Clinical Engineering (Healthcare) Technology Foundation, Jan/March 2007, <http://thehtf.org/white%20paper.pdf> Accessed 9/28/2015.

Kiekkas, Panagiotis, Knowledge of pulse oximetry: comparison among intensive care, anesthesiology and emergency nurses, *Journal of Clinical Nursing*, 22, 828–837, <http://www.ccforum.com/content/19/1/272> Accessed 9/28/2015.

Creighton Graham, K and Cvach, M, Monitor Alarm Fatigue: Standardizing Use of Physiological Monitors and Decreasing Nuisance Alarms, <http://ajcc.aacnjournals.org/content/19/1/28.short> Accessed 9/28/2015.

Siebig, S., et al., Intensive care unit alarms—How many do we need? *Critical Care Medicine* 2010; 38:451–456, <http://www.ncbi.nlm.nih.gov/pubmed/20016379>, Accessed 10/5/2015.

Pedersen, T. et al., Pulse oximetry for perioperative monitoring. Cochrane Anaesthesia Group, Published Online: 17 MAR 2014, Assessed as up-to-date: 30 JUN 2013, <http://onlinelibrary.wiley.com/doi/10.1002/14651858.CD002013.pub3/epdf>, Accessed 10/5/2015.

Neonatal SpO₂

S. Lakshminruslmha., et al., Oxygen targeting in preterm infants: a physiological interpretation, *Journal of Perinatology* (2015) 35, 8–15 <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4281291>.

Schmidt B., et al., Effects of Targeting Higher vs Lower Arterial Oxygen Saturations on Death or Disability in Extremely Preterm Infants, *JAMA*, May 22/29, 2013—Vol 309, No. 20 2111-2120, <http://jama.jamanetwork.com/article.aspx?articleid=1684963>.

Ahmed, S. et al., Effect of Averaging Time on Desaturations and Time in “Target”, *Pediatrics* 2010; 125 e115 -e121, <http://pediatrics.aappublications.org/content/125/1/e115.long>.

Vagedes J. et al., A conversion formula for comparing pulse oximeter desaturation rates obtained with different averaging times. *PLoS One*. 2014 Jan 28;9(1):e87280. doi: 10.1371/journal.pone.0087280. eCollection 2014. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3904986>.

Poets, C., et al., Association Between Intermittent Hypoxemia or Bradycardia and Late Death or Disability in Extremely Preterm Infants, *JAMA* August 11, 2015 Volume 314, Number 6, pages 595-603, <http://jama.jamanetwork.com/article.aspx?articleid=2425743>.

Castillo, et al., Pulse Oxygen Saturation Levels and Arterial Oxygen Tension Values in Newborns Receiving Oxygen Therapy in the Neonatal Intensive Care Unit: Is 85% to 93% an Acceptable Range?, *Pediatrics*, Vol. 121 No. 5 May 1, 2008, pp. 882 -889 (doi: 10.1542/peds.2007-0117) <http://pediatrics.aappublications.org/content/121/5/882.long> Accessed 10/7/2015.

General SpO₂ Tutorials

Basic pulse oximetry tutorials: http://www.howequipmentworks.com/physics/respi_measurements/oxygen/oximeter/pulse_oximeter.html.

http://www.who.int/patientsafety/safesurgery/pulse_oximetry/tr_material/en/ (also available in other WHO official languages).

General Clinical Alarms

AAMI Foundation Clinical Alarm Systems
<http://www.aami.org/foundation/alarms>.

Coalition for Alarm Management Safety
http://www.aami.org/foundation/alarms_coalition/.

Check out Browse Topics: Alarms which is more up to date. http://www.aami.org/newsviews/browsetopics.aspx/Clinical_Alarm_Management?id=26.3.

Healthcare Technology Foundation Clinical Alarms Improvement
<http://thehtf.org/clinical.asp>.

2011 National Clinical Alarms Survey
http://thehtf.org/documents/2011_HTFAlarmsSurveyOverallResults.pdf.

Impact of Clinical Alarms on Patient Safety
<http://thehtf.org/documents/White%20Paper.pdf>.

American Association of Critical-Care Nurses Alarm Management
<http://www.aacn.org/wd/practice/content/practicealerts/alarm-management-practice-alert.pcms?menu=practice>.

Veterans Administration Patient Safety Assessment Tool
http://www.aami.org/htsi/alarms/pdfs/PSAT_Clinical_Alarms_Safety.pdf.

POSITION PAPER: Guidelines for the Use of Home Pulse Oximetry in Infants and Children, California Thoracic Society, 2012. Accessed 9/27/2015. https://www.calthoracic.org/sites/default/files/pdfs/CTSpositionPaper_Guidelines%20for%20the%20Use%20of%20Home%20Pulse%20Oximetry%20InfantsChildren_2012.pdf.

The ECRI Alarm Safety Handbook:
https://www.ecri.org/components/Pages/Alarm_Safety_Handbook.aspx?tab=1
Strategies, Tools, and Guidance is an all-encompassing, 108-page reference manual and workbook intended to help you design and implement alarm management safety practices to meet the Joint Commission's 2014 National Patient Safety Goal—and keep your patients out of harm's way. Cost is \$395.

The Joint Commission Announces 2014 National Patient Safety Goal (NPSG.06.01.01) on clinical alarm safety for healthcare organizations and critical access healthcare organizations. *Joint Commission Perspectives*, July 2013, Volume 33, Issue 7,
http://www.jointcommission.org/assets/1/18/JCP0713_Announce_New_NSPG.pdf Accessed 10/5/2015.

Novel Approach to Cardiac Alarm Management on Telemetry Units *J Cardiovasc Nurs.* 2014 Sep-Oct;29(5):E13-22.

ANSI/AAMI ES60601-1:2005/(R)2012, Medical electrical equipment—Part 1: General requirements for basic safety and essential performance.

ALARMS

Discuss alarm default baseline levels based on the care area and cohort of patients. (Evaluate certain patient conditions where customized settings can safely be made to reduce erroneous alarms).

- What alarms are generated by the device?
- Is staff allowed to make patient specific alarm default changes?
- Does your current equipment have the ability to track desired data over time (e.g. frequency of alarms, reason for alarm, etc.)?

Gather data to determine baseline alarm numbers and types of SpO₂ alarms to use as markers to demonstrate improvements as changes are effected.

Are there a subset of patients that can be identified that are at higher risk for complications and would benefit from SpO₂ monitoring (i.e., risk stratification)?

Discuss alarm default baseline levels based on the care area and cohort of patients. (Evaluate certain patient conditions where customized settings can safely be made to reduce erroneous alarms).

Machine Alarms

These are alarms that are typically associated with the pulse oximeter itself. Examples of these are: low battery alarm, patient sensor disconnects, and machine sensor disconnect. These are intended to give the clinician early warning that either monitoring has ceased to exist or soon will. These alarms are important and should be addressed in a timely manner.

Patient Alarms

These alarms are directly related to patient condition and can either serve as a nuisance, or can signify a serious life threatening condition with the patient. The alarms typically include high and low SpO₂ reading, and high and low heart rate.

There are many factors that affect the precision of these patient alarms. Patient movement may cause artifact that will make determining whether or not these alarms are legitimate care concerns or not. These artifact alarms contribute to alarm fatigue and much work is being done to avoid this. Many producers of pulse oximetry technology have worked hard to determine the best way of reducing "nuisance" alarms caused by artifact. These changes in internal algorithms often include "averaging" of physiologic readings and "delay" in reporting short lived alarms. Although this may seem like a reasonable approach to these nuisance alarms, overall they may reduce the sensitivity and correlation with "real" physiologic changes with the patient. Other influences that may affect the accuracy and usefulness of pulse oximetry will be discussed later in this document.

Addressing pulse oximetry alarms

Seemingly intuitive, the first step in addressing any pulse oximetry alarm is to evaluate the patient and look for distress. High and low heart rate alarms should be correlated with patient condition. As an example a high heart rate could be associated with respiratory distress, pain, anxiety, or artifact. A low heart rate could be associated with hypoxemia, airway obstruction or the result of narcotics or other pharmacological agents. At any rate, these acute changes of heart rate should be considered real until corroborated with checking the pulse on a second site.

Desaturations

When artifact is present or when pulse oximetry alarms are not set appropriately, they can often lead to constant and/or nuisance alarm conditions that contribute to alarm fatigue. With that said, these alarms must be set with the patient's current clinical condition in mind. It is with this hope that by having alarms set appropriately, healthcare providers are only alerted to conditions that require intervention not false alarms that only serve to be a nuisance or for conditions that do not necessitate an intervention. Currently, there is little evidence-based literature published on pulse oximetry alarm settings. Every patient is unique and requires their pulse oximetry

alarm settings to be customized to their current condition and physiologic needs. Failure to properly set alarms will likely lead to constant conditions in which the alarm will be triggered. When this happens, alarm fatigue can set in creating either a false sense of security for the clinician or complete disregard for the alarm, thus creating an unsafe environment for the patient.

Duration of Alarms

When set appropriately, and with advancements in today's technology, desaturation alarms on pulse oximeters should (in theory) only alarm when a clinical condition occurs that warrants an intervention. Thus, should the pulse oximeter alarm continuously, the clinician should take immediate action to assess the patient for signs of hypoxemia.

In the event the patient's physical findings ARE NOT suggestive of a hypoxemic condition and the pulse oximetry alarm continues, the clinician should also consider the following:

- Confirm the presence of artifact (or lack thereof)
- Check to ensure the pulse oximetry probe is not malpositioned
- Check for clinical conditions that could impact the limitations/accuracy of the pulse oximetry monitor (see limitations section of this document)
- Contact the LIP immediately
- Consult with LIP for an arterial blood gas to be drawn

CLINICAL CONDITIONS

Chronic Conditions

There are chronic conditions where hypoxemia/hypoxia may be pre-existing. Consideration should be made when managing these patients. Lower thresholds may be tolerated in certain cases. Baseline conditions should be understood by the managing team so that acute or chronic changes can be recognized and dealt with. Pulse oximetry saturations of 88-90% are often considered to be baseline when chronic hypoxemia exists in the 50-60 mmHg range. Although monitoring should be customized according to chronic "irreversible" conditions, acute hypoxemia should be managed the same in all patients.

Some of these chronic conditions are listed below.

- Chronic Obstructive Pulmonary Disease (COPD)
- Cystic Fibrosis
- Pulmonary Hypertension
- Pulmonary Fibrosis
- Asthma
- Congestive Heart Failure (CHF)

Obesity

Obesity can precipitate acute and chronic hypoventilation and compressive atelectasis. These in turn may cause hypoxemia. This is especially true in those patients who are being managed with sedation and or analgesia.

Continuous monitoring should be initiated in patients that are obese and have risk factors for any of the above.

Acute Conditions

Acute causes of hypoxemia and hypoxia should be monitored closely for changes in gas exchange. It is important to avoid both profound hypoxemia and the use of high levels of oxygen concentration. It is typically accepted that one should maintain oxygenation at a point on the oxy-dissociation curve that leaves some room for slight deterioration before reaching the steep portion of the curve where quick decompensation occurs. This is usually somewhere between 90-94% depending on other factors such as acidemia, core temperature and hemoglobin levels.

Pneumonia

- Acute Respiratory Distress Syndrome (ARDS)
- Multi-System Organ Failure (MSOF)
- Asthma
- Congestive Heart Failure (CHF)

A large source of SpO₂ alarm burden is attributed to technical errors caused by mismanagement of SpO₂ sensors and cables.

The following are examples of workflows that contribute to SpO₂ technical errors and recommendations for mitigating the alarms:

- Improper placement of SpO₂ sensors may cause motion artifact and poor signal quality. Healthcare organizations may define protocols to periodically check sensor placement and signal quality to ensure accurate measurement.
- Disconnection of SpO₂ sensor when the patient is being transferred causes SpO₂ disconnection technical alarm notification. SpO₂ devices and patient monitors typically support a “smart” alarm state that disables SpO₂ technical alarms while the

SpO₂ sensor is being removed from the patient.

- SpO₂ sensors that have been removed from the patient but remain connected to the SpO₂ device or patient monitor may acquire ambient light that causes inappropriate SpO₂ measurements and technical error messages. SpO₂ sensors and cables need to be properly disconnected and stored during the process of turning over the patient's bed.

Core temperature can influence peripheral readings (controlled hypothermia for example) so consideration must be given to select a sensor type and site that will provide accurate readings under these conditions.

- Complementary (or competing) alarm settings must also be considered. When evaluating the alarm setting for SpO₂ pulse rate, consider the HR alarm level is setting. If these differ, there could be instances of competing alarms.

Order sets for the use of pulse oximetry help direct providers to selecting the appropriate level of monitoring for each patient. Boston Medical Center (BMC) developed electronic orders to guide the providers through a number of prompts to ensure that they consider the patient condition and default alarm considerations for patients.

SpO₂ Lower Limit: Defaulted 88% but can be opened by LIP to adjust default 75% to 95%

Changes to Standard Alarms: Drop down /LIP may select more than - None, Known chronic hypoxemia may lower SpO₂ low alarm to 85% without additional orders, Continuous pulse oximetry not required when out of bed.

DATA

Trended Data

Capturing trends in pulse oximetry data is of great importance in the care of patients being monitored with this technology (either by continuous or intermittent monitoring). It is important to note that both intermittent and continuous saturation monitoring only provides the clinician with a singular data point at one point in time. A SpO₂ of 92% may be reflective of a safe, but less than ideal oxygen saturation; however, this singular data point means very little without a) a baseline measurement to compare it to; and b) trended data to give a numerical and graphical depiction of what has historically taken place with the patient over a defined period of time. It is through trended data that the clinician can monitor the oxygen saturation of a patient and make determinations whether or not the patient's oxygenation status has been stable over a defined period of time, whether it is improving or whether or not it is on the decline.

Technologically advanced software in today's pulse oximeters and electronic health record platforms provide the clinician with the ability to download trended data and is an assessment all clinicians should consider when examining their patients.

Data are needed to determine which SpO₂ alarms, (technical versus patient related) in relation to specific patient populations and hospital units, are causing the most false or nonactionable alarms. This knowledge is required before determining which SpO₂ alarm management strategies will work best across the organization or in a particular unit, (strategies such as changing SpO₂ alarm default parameter setting across the organization, teaching clinicians how to further customize the settings based on individual patient physiological realities, incorporating alarm delays, employing middleware to assist in triaging alarm signals, etc.

Clinical improvements can be made only after a baseline alarm assessment has been established. Additionally, optimizing SpO₂ alarm signals requires the development of repeatable processes; otherwise, solutions may not translate to other clinical care areas.

Therefore, to make a meaningful reduction in SpO₂ alarm signals, data should be collected to document baseline alarm conditions in the unit-care environments where SpO₂ measurements are employed. Baseline data to be collected include the current default parameter settings, frequency of alarm customization of default parameter

settings, criticality of the alarm conditions, and number and type of alarms per patient per day. Using alarms per bed per day based on the total bed count (i.e., occupied and unoccupied) can be a problem in that beds are not always occupied; therefore, a metric based on occupied bed count per day is preferable, especially for units with variable census.

TROUBLESHOOTING

Note: The first thing to assess is whether all the patients who are on continuous O₂ Sat monitoring require this? This is particularly true if the patient is progressing in activity and able to get up and down themselves. Is there an opportunity to have intermittent O₂ Sats on these patients? This is something to explore with patient care team.

For patients identified as “Vasoconstricted for Home” losing signal

Exchange finger probe for ear probe. Discuss with manager as these will be a special order and staff will have to know where to stock them.

For O₂ probe is off the patient alarms

Here are some troubleshooting suggestions

When taking probe off for eating or ambulating, physically disconnect the cable and probe from the monitor as this will take away that alarm. This would be important for you to ask your Physical Therapy colleagues to do as well. Remember to reconnect to the patient and monitor.

For patients who are agitated because of probe slipping off, change to disposable sticky probes so probe will stay on more securely. Unit may need to increase inventory but really should only be used for patients who cannot be safely monitored on a reusable probe.

Signal quality issues

1. Change probe finger from index to middle finger or middle finger to index finger.
 2. Place probe on toe.
 3. If patient is cold, a hot pack can increase blood flow to that area and potentially generate a reliable pleth waveform.
 4. If blood pressure cuff is present and on auto-cycle, ensure that the sat probe is on the opposite arm.
-

NOTES

[illegible]

DIAMOND LEVEL



PLATINUM LEVEL

GE Healthcare



GOLD LEVEL



AAMI FOUNDATION