

# **“Clinical Alarm Safety in Respiratory Care”**

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# Learning Objectives

- Describe and discuss the concept of alarm fatigue.
- Describe the different patient / equipment alarms related to respiratory care.
- Describe different approaches to monitoring mechanical ventilators in clinical practice.

# 2022 Hospital National Patient Safety Goals

- Improve the accuracy of patient identification.
- Improve the effectiveness of communication among caregivers.
- Improve the safety of using medications.
- Prevent mistakes in surgery
- Reduce the risk of health care–associated infections.
- Identify patient safety risks
- **Reduce patient harm associated with clinical alarm systems.**

# Clinical Alarm Systems



**WHAT'S THE**  
**BIG DEAL?**

# Alarm Fatigue

- Alarm fatigue occurs when clinicians, primarily bedside caregivers, become desensitized to safety alarms from physiologic monitors and equipment.
- The large volume of alarms can lead to missed alarms or delayed response as caregivers stop reacting to them.
- False or “nonactionable” alarms increase alarm fatigue and cause clinicians to start doubting the reliability of the alarms.

# Alarm Fatigue

- From 2005-2008, the FDA reported 566 deaths related to monitoring device alarms.
- The large volume of alarms can lead to missed alarms or delayed response as caregivers stop reacting to them.
- False or “nonactionable” alarms increase alarm fatigue and cause clinicians to start doubting the reliability of the alarms.

# Alarm Fatigue

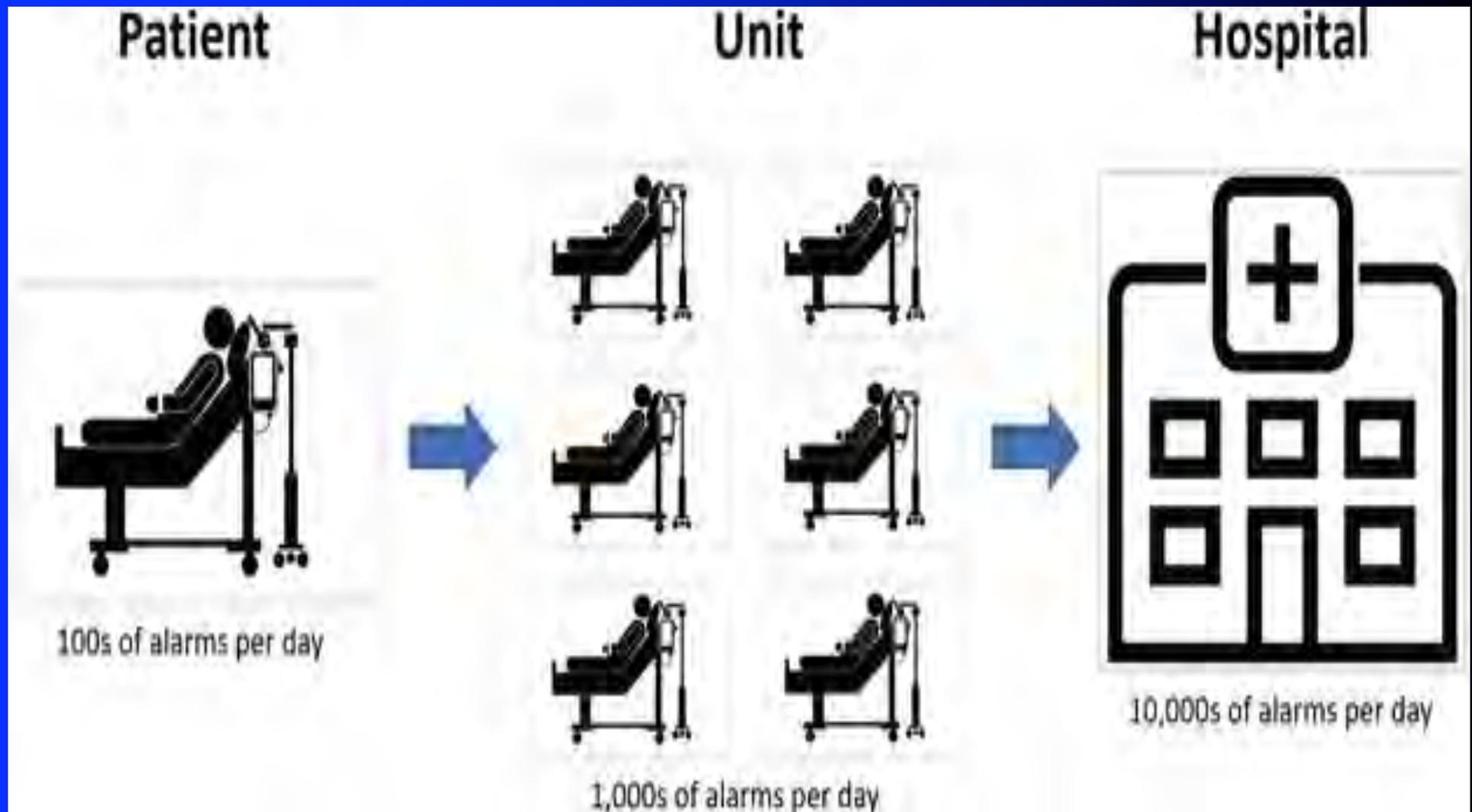
- A study at John Hopkins Hospital looked at one 12-day alarm system analysis and found 58,764 alarms - an average of 350 per patient per day.
- Average of over 14 per hour or one every 4 minutes!

# Alarm Fatigue

- Pulse oximetry is one of many monitors that contribute to false alarms and alarm fatigue.
- 2021 study by Burg, et. al. reviewed 18,080 pediatric patients from January, 2019 through September of 2020 (excluding intensive care and cardiology units)
- Results showed an average of 29.6 pulse oximetry monitor alarms sounded each day of which 38.7% were for values  $\geq 88\%$ .

Berg, Kathleen; Johnson, David; Nyberg, Ginny; Ausmus, Andrew; Claeys, Christine; Wilkinson, Emily; and Clark, Nicholas, "Reducing alarm burden by promoting judicious ordering of continuous pulse oximetry" (2021). *Presentations*.  
<https://scholarlyexchange.childrensmercy.org/presentations/36>

# Alarm Fatigue



The Joint Commission. Sentinel Event Alert. 8 April 2013;(50):1-3

# Types of Alarms

Signal	Artifact source	Parameter
<b>Ventilatory alarms</b>		
Pulse oximetry	Movement Injection of contrast dye Interruption of blood-flow by non-invasive blood pressure Measurement Ambient light	Oxygen saturation Pulse frequency
Capnography	Occlusion of CO <sub>2</sub> -line (by kinking or built up fluid) Ventilator circuit leakage Atmospheric pressure variations Suctioning Dead space in measurement circuit	End-tidal CO <sub>2</sub> Inspired CO <sub>2</sub> Respiratory rate
<b>Hemodynamic Alarms</b>		
EKG	Electrosurgical interference Power-line interference Movement artifacts (patient movement, positioning) Electrode instability or electrode distortion EMG/neuromonitoring interference Incorrect connection or lead contact Pacing/defibrillation Abnormally tall T-waves mistaken as QRS-complex MRI interference	Heart rate, ST-values Arrhythmia detection
Non-invasive blood pressure	Movement Inadequate size or cuff position Compression of cuff by external forces (surgeon or equipment pressing against the cuff) Kinked cuff tubing and leaking cuff bladder	Systolic, diastolic blood pressure Mean arterial pressure
<b>Other Alarms</b>		
Temperature	Dislocated sensor	Temperature

# Alarm Hazards

- The FDA received more than 2,500 adverse event reports associated with ventilator use in 2010.
- Nearly 1/3 of the events were alarm-related.
- Some events involved deteriorating patient conditions but many others were preventable malfunctions or human error.

# Alarm Hazards

- ECRI added “Alarm Hazards” to its annual “Top 10 Health Technology Hazards” list in 2012 which remained #1 thru 2014
- In 2015, “Ventilator Disconnection Not Caught because of Mis-set or Missed Alarms” was listed separately from “Alarm Hazards” and was #5, moved up to #3 by 2017 and remained on list through 2020.



# Sentinel Event

- A “Sentinel Event” is defined by the Joint Commission as a Patient Safety Event that reaches a patient and results in any of the following:
  - Death
  - Permanent harm
  - Severe temporary harm and intervention required to sustain life
- An event can also be considered sentinel event even if the outcome was not death, permanent harm, severe temporary harm and intervention required to sustain life.

# Joint Commission Sentinel Event Alert

- Identifies specific types of sentinel events, describes their common underlying causes, and suggests steps to prevent occurrences in the future.
- Issue 50, April 8, 2013:  
“Medical device alarm safety in hospitals”
  - JC database of sentinel events from 2009-2012 included 98 alarm related events
  - 80 events resulted in death
  - 13 events resulted in permanent loss of function
  - 5 events resulted in additional care / extended stay

# Joint Commission Sentinel Event Alert

## Issue 50 – 4/8/2013

- Major contributing factors to events
  - Absent or inadequate alarm system (30)
  - Improper alarm settings (21)
  - Alarm signals not audible in all areas (25)
  - Alarm signals inappropriately turned off (36)
- Sentinel events typically have multiple contributing factors.

# When An Alarm Isn't Always Alarming

- Two month study performed in 6 units including 154 beds at Stanford University Medical Center.
  - 318,000 cardiac arrhythmia monitor alarms which equates to an average of 887 alarms per bed, per day
  - 43% of the alarms were “non-critical” or actionable
  - 38% of alarms were for PVCs requiring no treatment
  - **3.6% of alarms indicated critical events**
  - **19 of 318,000** alarms indicated “Code Blue” events or 0.2% of all events....
- Numerous other studies have looked at the % of “actionable” alarms with results from 0.2-36%

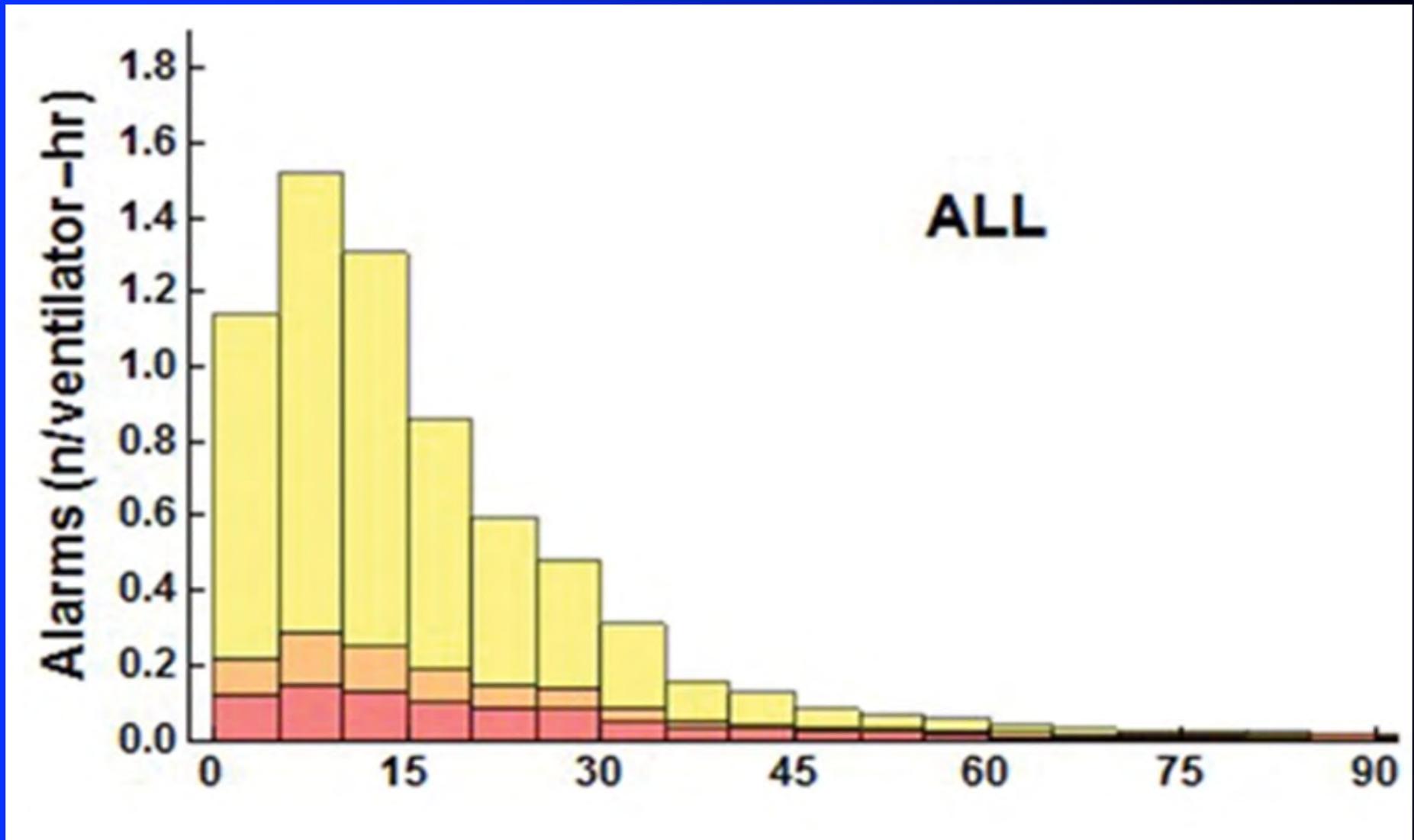
# What About Ventilator Alarms Frequency?

- 2020 published study done at John Hopkins Hospital
- Prospective observational study that included 3 ICUs cardiovascular surgical ICU (CVSICU), medical ICU (MICU), and neurocritical care unit (NCCU) in March of 2017
- Ventilators included PB 840 in all units and the Hamilton G5 in CVSICU as well
- Included alarm notifications occurring at time zero as the initial notification cascade
- Notifications at the 15-second mark were tallied as an additional notification cascade

# What About Ventilator Alarms Frequency?

- 1,555 ventilator hours included in study
- 10,905 total ventilator alarms initiated
- The overall mean number of alarms per hour by unit:
  - 6 (CVSICU) – SD 3
  - 7 (MICU) – SD 4
  - 8 (NCCU) – SD 2
- Overall, ventilator alarms did not resolve within 15 seconds 40% of the time.

# What About Ventilator Alarms Frequency?



Cvach, M. et. al, Ventilator Alarms in Intensive Care Units: Frequency, Duration, Priority, and Relationship to Ventilator Parameters, *Anesthesia & Analgesia*: January 2020 - Volume 130, Issue 1, pages 9-13

# What About Ventilator Alarms Frequency?

- Most frequently triggered alarms in all 3 ICUs:
  - High inspiratory pressure (34.2%)
  - High respiratory rate (17.8%)
  - Low expired mandatory tidal volume (12.9%)
- Alarm priority (determined by type of ventilator)
  - Low priority (75.2%)
  - Medium priority (10.2%)
  - High priority (13.7%)

Note: In CVSICU, high priority alarms accounted for only 8.6% of PB840 alarms, but 89.8% of G5 alarms

# Ventilator Alarm Big Part of Overall Alarms

- Other studies have looked at overall % of ICU alarms that are caused by the ventilator.
  - Chambrin, et. al – 38%
  - Lipton, et. al – 42%
  - Lawless, ST – 31%
  - Joshi, et. al – 12%

# Alarm Priority Types

Alarm type	Message bar	Alarm lamp / Alarm status indicator	Audio	Action required
High priority	Red, with alarm message	Red, flashing <sup>41</sup> Alarm status indicator on the front of the ventilator body is lit	A sequence of 5 beeps, repeated until the alarm is reset.	The patient's safety is compromised. The problem needs immediate attention.
Medium priority	Yellow, with alarm message	Yellow, flashing <sup>41</sup> Alarm status indicator on the front of the ventilator body is lit	A sequence of 3 beeps, repeated periodically.	The patient needs prompt attention.
Low priority	Yellow, with alarm message	Yellow, solid <sup>41</sup> Alarm status indicator on the front of the ventilator body is lit	Two sequences of beeps. This is not repeated.	Operator awareness is required.
Technical fault	Red, with the text <i>Technical fault: xxxxxx</i>	Red, flashing Alarm status indicator on the front of the ventilator body is lit	Same as for high-priority alarm, if technically possible. At a minimum, a continuous buzzer tone. The buzzer cannot be silenced.	<ul style="list-style-type: none"> <li>• Provide alternative ventilation.</li> <li>• Turn off the ventilator.</li> <li>• Have the ventilator serviced.</li> </ul>

## Hamilton G5 Ventilator

# Alarm Priority – PB 980 Ventilator

- **High Priority** (Red flashing light & a sequence of 5 tones that repeats twice, pauses, then repeats again). - Immediate attention required to ensure patient safety.
- **Medium Priority** (Yellow flashing light & a sequence of 3 tones) - Prompt attention needed.
- **Low Priority** (Yellow solid light) - A change in the patient-ventilator system has occurred.

# Alarm Priority – Hamilton G5 Ventilator

- High Priority (Red flashing light & a sequence of 5 tones that repeats until alarm is reset) – The patient's safety is compromised. The problem needs immediate attention.
- Medium Priority (Yellow flashing light & a sequence of 3 tones, repeated periodically) - The patient needs “prompt” attention.
- Low Priority (Yellow solid light & 2 sequences of 1 beep) - Operator awareness is required.

# What IS a “High Priority” Ventilator Alarm?

- Hamilton G5 manual includes 14 pages of different alarms.
- 90 total alarms are possible
  - 39 Low Priority
  - 25 Medium Priority
  - 26 High Priority (includes 1 “technical fault”)
- PB 980 manual lists similar number of alarms but many alarms have the ability to be activated as a low, medium or high priority.

# What IS a “High Priority” Ventilator Alarm?

- Some alarms have “general” acknowledgement of “high priority” importance
  - Apnea
  - Check Circuit / Tubing
  - Disconnect
  - Exhalation Obstructed
  - Low Pressure
  - Oxygen Supply

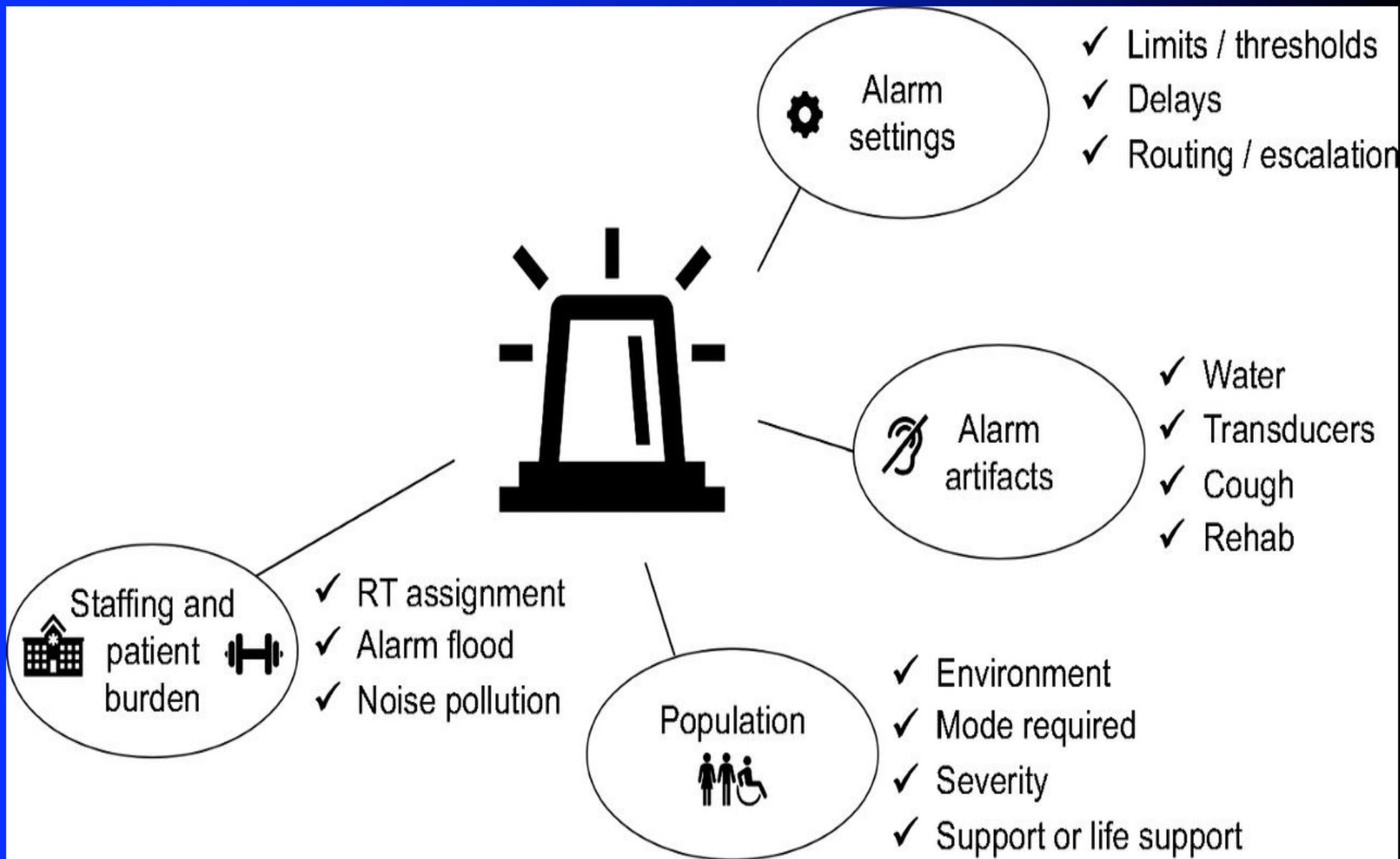
# What IS a “High Priority” Ventilator Alarm?

- Some alarms have may activate as one alarm type but actually be a higher or lower alarm type.
  - High Pressure Limit
    - Cough vs dec. compliance vs airway obstruction)
  - Low Tidal Volume or Low Minute Ventilation
    - Known vs unknown - how large of a leak is it?
    - Leak in circuit / airway / chest tube
    - Lower RR due to sedation vs change in neuro status

# What IS a “High Priority” Ventilator Alarm?

- Some alarms have may activate as one alarm type but actually be a higher or lower alarm type.
  - High / Low Respiratory Rate
    - Patient awake, agitated, etc?
    - Normal for current patient status or is it a change?
  - Low Air Pressure
    - Newborn (high priority) vs Adult (medium priority)

# Issues Effects Alarm Settings



# Pop Quiz!!!

- How should the low tidal volume alarm be set on a patient in the A/C mode?
- How should the low tidal volume alarm be set if the patient is changed to CPAP with Pressure Support?
- What rate should the High Respiratory Rate alarm be set at?
- How many liters should the Low Minute Volume alarm be set?



# Standard Alarm Settings

- Currently, there no existing national standard settings for ventilator alarms. Different RT texts give different alarm setting values or a wide range.
- There have been multiple attempts to address alarm fatigue including the use of middleware to contact the RT when certain alarms are sounding or using external room alarms that sound when the ventilator alarm has activated for a specified period of time (i.e 10 seconds)

# Standard Alarm Settings

- One of the biggest causes of alarms that either over OR under activate is the Respiratory Therapist themselves.
- Many RTs set alarms that are too far above or below the patient's normal or current level.
- This is a result of not having standard guidelines, a lack of RT knowledge, laziness and more.

## Standard Alarm Settings

- One easy solution to help reduce alarm errors is to use.....

# COMMON SENSE

- RTs should not set alarms based on some random values but to set them to a *level where they would want the ventilator to notify them of a significant change in patient status.*

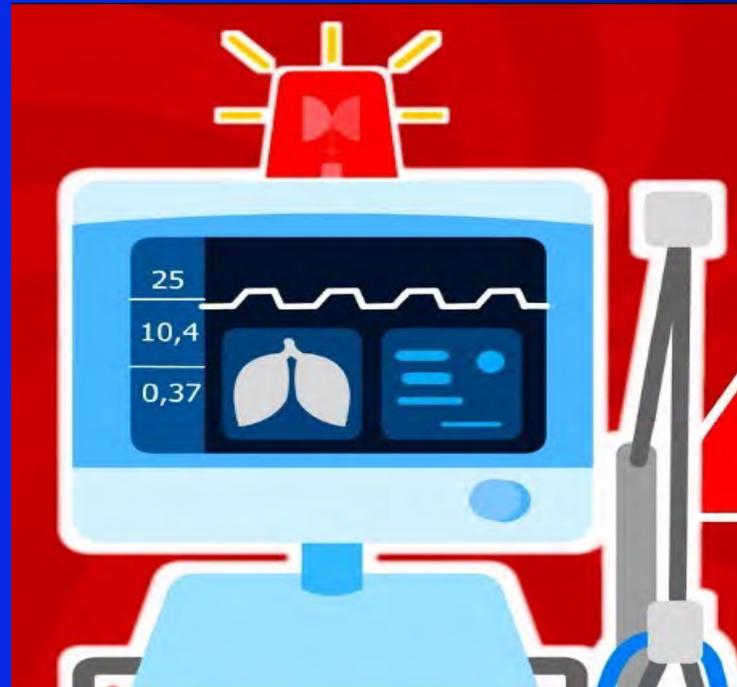
# Hospital of the University of Penn - Pavilion



- 1.5-million-square-foot, 17-story facility with 504 private patient rooms and 47 operating rooms.
- All private patient rooms

**CAN YOU  
HEAR THIS?**

**CAN YOU  
SEE THIS?**



**What if you aren't in the room???**

# Reacting To Ventilator Alarms

- New push for patient comfort (big rooms, sound eating construction, etc.) are great at doing their jobs – maybe too great!
- Within 48 hours of opening a patient's ventilator circuit disconnected from their E-T tube.
- The ventilator alarm sounded continuously yet no one heard it despite the fact that an RT was in the room next door on one side and an RN was in the room on the other side

# Reacting To Ventilator Alarms

- Immediate mitigation steps included:
  1. New policy that the room door must be kept open for all ventilated patients
  2. All ventilator alarms turned up to maximum volume
- Within 7 days another patient self-extubated occurred and once again no one heard the alarm.
- How? The door was closed due to a fire drill!

# Reacting To Ventilator Alarms

- MORE mitigation needed - but WHAT?
- Contacted ECRI to see how other hospitals with similar problem resolved it. Of the 20% of facilities that actually use some type of alarm system, most were using a computerized middleware solution
- This was not an option for us as physiologic alarms were utilizing that type of system.
- Two committees were formed – one looking at a short-term fix and another at a longer term fix.

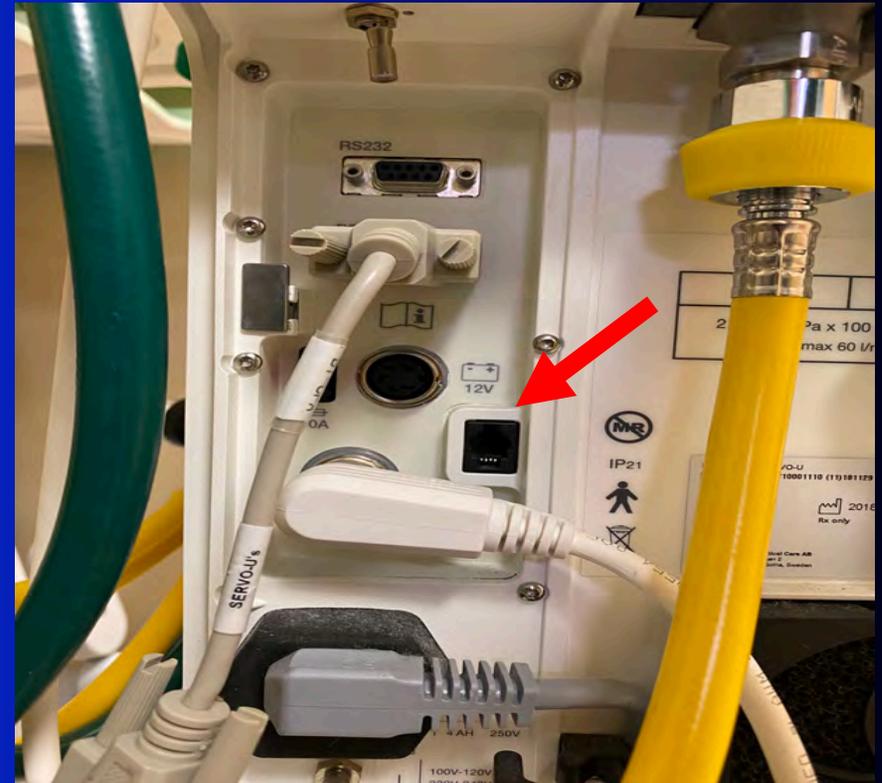
# Short Term Immediate Fix

- Need for an EXTERNAL alarm – preferably to include both visual and audio alerts
- If possible, needed to utilize existing infrastructure
- Given the goal of short term, needed cost to be reasonable.
- Given large number of ventilators and ICUs, needed easy to install, teach / learn, etc..

## Short Term Immediate Fix

- Identified one system used at a local community hospital that attached the ventilator to an external audio alarm with a cable to the wall.
- Unfortunately no such alarm system existed in new Pavilion building....or did it?
- Hill-Rom call bell system utilizes external audio and visual alarm.
- How do we connect ventilator to the Hill-Rom system and if we can, would that work???

# Connecting Ventilator to Hill-Rom Call Bell



- Ventilator vendor contacted and they identified cable that connects to ventilator and vendor that makes them (small company in Florida)
- Plugs into “phone jack” in back of ventilator

# Connecting Ventilator to Hill-Rom Call Bell



- The other end of the cable plugs into the 1/4" Hill-Rom wall jack which is normally utilized for specialty call bell devices (blow tube, push pad, etc.)
- Needed to find an adaptor so these devices could still be used – enter Curbell adaptor which plugs into different, unused port in wall.

# Connecting Ventilator to Hill-Rom Call Bell

- After contacting Hill-Rom, determined that call bell needed to be programmed so that the ¼” jack would show “Equipment” alarm when activated (instead of nurse call)
- Audible alarm can be changed to a different sound and one that was unique from ALL other alarms used in the hospital was selected (sounds like a cell phone ringing)
- Tested the system and it worked! However, *every* alarm activated on the ventilator (cough, leak, etc.) also activated the external audio and visual alarms. Tons of alarms which would lead to ALARM FATIGUE

# Finally A Solution!

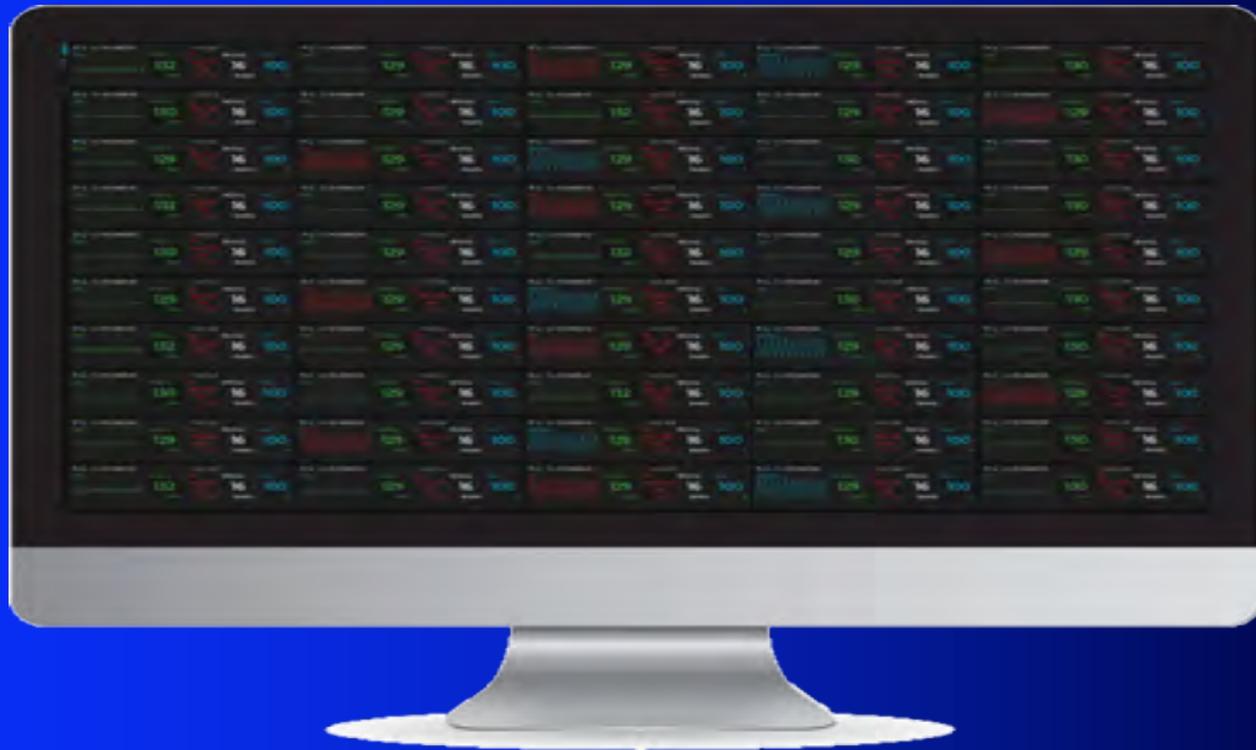


- After searching the internet, identified a small company that manufactures much smaller call bell systems for nursing homes, etc..
- System included an alarm timer delay device which is inserted between the ventilator and the Hill-Rom box. Timer can be set to any period of time (in seconds)

# Finally A Solution!

- Timer was inserted and set to 10 seconds and tested
- After successful test, initiated trial in 12 beds of HVICU
- Initial feedback was “It’s too loud” and “Too many alarms”. Loud was ok but decision made to increase time delay to 15 seconds – MUCH better!
- System is now live in all of HVICU and Surgical ICU. Other units will follow once additional timers are received!

# What's the Long Term Solution?



- Sickbay is a multi-function computer platform that integrates physiological monitoring along with a LOT more – including ventilator alarms.
- Currently in use in our Neuro ICU with additional monitors to be installed and system installed in all ICUs

# Take Home Notes

- National Patient Safety Goals include the reduction of patient harm associated with clinical alarm systems.
- Alarm fatigue is real and can lead to even more events as ALL alarms begin to be ignored or “not heard”
- RTs can be part of the solution or part of the problem!  
Set realistic alarms not just “cookbook” settings.
- There ARE solutions that can help alert RTs and other caregivers when a patient is in danger but there is no single answer that works for all facilities. Do your research and find something that works for you!

# Thanks!

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