Wake Up From Alarm Fatigue: Using Our Monitors Wisely

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Disclosures

- Philips Medical  Honorarium
  Collaborated on hospital based alarm project

- ClearFlow, Inc.  Honorarium
  Scientific Advisory Board
Objectives

- Define the concept of “alarm fatigue” and factors that contribute to it's occurrence
- Identify essential provisions and timelines for implementation of the U.S. National Patient Safety Goal for alarm management
- Discuss evidence based solutions to appropriate management of clinical alarms
The Problem With Alarms

- Alarms ranked as #1 top technology safety hazard by the Economic Cycle Research Institute (ECRI)
- 86% - 99% of alarms are *non-actionable*
- Fire alarms work because they are a RARE event!
- When the *same alarm* sounds for a life threatening arrhythmia versus brushing your teeth, then “Nothing is an Emergency”
Responding to Alarms

Alarm sounds . . . . .

- Hear the alarm
- Determine meaning/interpret
- Prioritize if immediate action necessary
- Distinguish what action is appropriate
- Respond
  - Patient care – resuscitation response, notifications
  - Adjust monitor parameters/fix equipment
Alarm Fatigue is a Significant Problem

- **Alarm Fatigue – The Boy Who Cried Wolf!**
  - Occurs when staff members are exposed to an excessive number of non-actionable, “nuisance” alarms
  - Staff become desensitized: recent study showed 47% of alarms are not responded to
  - Result is sensory overload:
    - Staff frustration
    - Delayed alarm responses
    - Missed alarms
    - Adverse patient safety events

Modified From: American Association of Critical-Care Nurses, Alarm Fatigue Tool Kit, 2013
Alarm Fatigue Terminology

**Actionable Alarm** – *Requires* intervention

- To avoid an adverse event: change in patient status merits action to reverse or prevent deterioration
- To maintain appropriate monitoring: technical problem needs corrected (e.g., leads off, \(\text{SpO}_2\) sensor disconnected) – actionable because REAL events may be missed

**Non-actionable [nuisance] alarm** – *Does not* require intervention

- True: alarm was accurate but unimportant
  - Triggered by anticipated event (e.g., suctioning or moving a patient) and transient/self-correcting
  - Triggered due to tight limits rather than actionable ones
- False: alarm error (e.g., artifact)
Practice Standards for Electrocardiographic Monitoring in Hospital Settings: An American Heart Association Scientific Statement From the Councils on Cardiovascular Nursing, Clinical Cardiology, and Cardiovascular Disease in the Young: Endorsed by the International Society of Computerized Electrocardiology and the American Association of Critical-Care Nurses

Barbara J. Drew, Robert M. Califf, Marjorie Funk, Elizabeth S. Kaufman, Mitchell W. Krucoff, Michael M. Laks, Peter W. Macfarlane, Claire Sommargren, Steven Swiryn and George F. Van Hare

Circulation. 2004;110:2721-2746
Insights into the Problem of Alarm Fatigue with Physiologic Monitor Devices: A Comprehensive Observational Study of Consecutive Intensive Care Unit Patients

Barbara J. Drew¹*, Patricia Harris¹, Jessica K. Zègre-Hemsey², Tina Mammone³, Daniel Schindler¹, Rebeca Salas-Boni¹, Yong Bai¹, Adelita Tinoco¹, Quan Ding¹, Xiao Hu¹

- State of the art technology used to collect alarm data
- 7-lead ECG, SpO2/resp, parameter alarms & user settings
- 5 units (ICU, CCU, neuro ICU), 461 patients, 31-days

PLoS ONE 9(10): e110274. doi:10.1371/journal.pone.0110274
Alarm Fatigue Findings

- Total number of alarms 2,558,760
- Arrhythmia alarms 1,154,201
- Parameter alarms 612,927
- Technological 791,632
- Audible alarms 381,560

Audible alarms per patient bed per day = 187!

### Table 6. Accuracy of 12,671 Arrhythmia Alarms.

<table>
<thead>
<tr>
<th>Alarm Type</th>
<th>Number of Alarms</th>
<th>Number of Patients</th>
<th>Number of True Positives</th>
<th>Number of False Positives</th>
<th>False Positive Rate</th>
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<tbody>
<tr>
<td>1. Asystole</td>
<td>792</td>
<td>113</td>
<td>260</td>
<td>531</td>
<td>67.0%</td>
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<tr>
<td>2. Ventricular Fibrillation</td>
<td>158</td>
<td>19</td>
<td>107</td>
<td>51</td>
<td>32.3%</td>
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<tr>
<td>3. Ventricular Tachycardia</td>
<td>3861</td>
<td>183</td>
<td>502</td>
<td>3352</td>
<td>86.8%</td>
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<tr>
<td>4. Accelerated Ventricular Rhythm</td>
<td>4361</td>
<td>99</td>
<td>224</td>
<td>4135</td>
<td>94.8%</td>
</tr>
<tr>
<td>5. Pause</td>
<td>2239</td>
<td>140</td>
<td>272</td>
<td>1963</td>
<td>87.7%</td>
</tr>
<tr>
<td>6. Ventricular Bradycardia</td>
<td>1260</td>
<td>39</td>
<td>40</td>
<td>1219</td>
<td>96.7%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>12671</strong></td>
<td><strong>1405</strong></td>
<td><strong>11251</strong></td>
<td></td>
<td><strong>88.8%</strong></td>
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</table>

*15 alarms were indistinguishable: 1 Asystole, 7 VTach, 2 AccVent, 4 Pause, and 1 Ventricular Brady.

doi:10.1371/journal.pone.0110274.t006

This is a Patient Safety Issue!

Joint Commission for Accreditation of Hospital Organizations (JCAHO) Sentinel Event Alert, 2013

- 98 alarm-related events reported (Jan, 2009–Jun, 2012)
  - 80: deaths
  - 3: permanent loss of function
  - 5: unexpected additional care or extended stay
- Major contributing factors to alarm-related events:
  - Absent or inadequate alarm system
  - Improper alarm settings *for patient*
  - Alarm signals turned off or not audible
  - Inadequate staff training
  - Alarm fatigue – the most common contributing factor
Key Components Needed in Policies & Procedures

NPSG.06.01.01: Improve the safety of clinical alarm systems

- Policies should address the following areas:
  - Clinically appropriate alarm settings
  - When alarms can be disabled or changed
  - Who can set, disable or change alarm parameters
  - Appropriate practices for monitoring
  - Appropriate responses to monitor alarms
  - Organizational processes for checking alarms for accuracy, appropriate operation, and detectability (audibility throughout unit)
This is **not** just for EKG alarms!

- Warming Devices
- SpO2 Monitors
- Foot Pumps
- Infusion Pumps
- Bed Alarms
- Ventilators/CPAP
- Hemodynamics
- Hemodynamics
ERCI Recommendations

1. Assemble a multidisciplinary team
   - Administrative sponsor (e.g., CNO, VP Quality)
   - Key medical staff
   - Nurse managers
   - Front-line nurses
   - Monitor technicians
   - Patient safety/risk manager
   - Clinical engineering staff
   - IT staff
   - Consult with others, as appropriate

2. Review recent events and near misses
   - Root causes
   - Frequency of alarm types
   - Aggregate of alarm types per care area/shift
   - Review remediation/results
   - Trends

3. Observe alarm coverage processes and ask nurses and other staff about their concerns
   - Routine rounding
   - Listen to staff concerns/problems
   - Map processes for alarm notification and response
   - Identify obvious problems
   - Excessive alarms
   - Difficulty in hearing alarms
   - Delayed alarm response
   - Pagers not being worn

4. Review entire alarm coverage system
   - Culture
   - Infrastructure
   - Practices
   - Technology

5. Identify patient safety vulnerabilities and potential failures
   - Failures
     - Delayed alarm response
     - Transport Communication Breakdown
     - Leads-off Apathy
     - Alarm Fatigue
   - Causes
     - Diffuse responsibility for alarm response
     - Competing priorities
     - Assumptions that someone else will respond
     - Excessive nuisance alarms

6. Develop realistic, implementable strategies to address underlying causes
   - Today’s Fixes
     - Proper skin prep
     - Proper electrode placement
     - Routine change of electrodes
     - Battery replacement every 24 hours
     - Elevate “Leads-Off Alarms” to crisis priority
   - Things to Consider
     - Delineate responsibility for alarm response
     - Develop a back-up plan with tiers of coverage
     - Delineate responsibility for back-up response
     - Implement two-way communication devices that would allow a nurse to request help
     - Develop an alarm escalation scheme
How Do Alarms Work?

- **Current Designs**
  - High sensitivity – detect even minute changes = frequent alarms
  - Low specificity – do not distinguish if real or important = frequent alarms

- **Threshold Technology**
  - Each alarm has a threshold that must be breached for it to sound (e.g., low HR at 50 bpm)
  - Each alarm as a separate threshold (HR vs SBP vs SpO2)
  - Thresholds are not integrated (e.g., asystole alarm & A-line BP 110/72)
  - Built in delays for “self correction” prior to alarm are possible

- **Current Options to Reduce Alarms Include**
  - Disabling the parameter
  - Changing the threshold
  - Increasing the delay
Potential Solutions

- Silence/limit alarms
  - Change default parameters to “actionable” ones
  - Increase our attentiveness to remaining alarms

- Add technology
  - “Smart” pagers
  - Increase specificity of alarm products

- Change provider/technology interface
  - Smart devices better integrated

- Telemetry criteria – fewer patients on monitor
Partnership with Philips for Alarm Management Assessment

Two week in-depth analysis of 4 units
Detailed alarm and clinician response data
# Categories of Alarms Captured

Potential alarms per category

<table>
<thead>
<tr>
<th>Red Arrhythmia Alarms</th>
<th>Yellow Arrhythmia Alarms</th>
<th>Red Bed Alarms</th>
<th>Yellow Bed Alarms</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Asystole</td>
<td>• PVC Alarms</td>
<td>• SpO2 Desat</td>
<td>• SpO2 High</td>
</tr>
<tr>
<td>• Vfib/Tach</td>
<td>• Beat Detection Alarms</td>
<td>• Apnea</td>
<td>• SpO2 Low</td>
</tr>
<tr>
<td>• Vtach</td>
<td>• Rate/Rhythm Alarms</td>
<td>• Invasive Line Disconnect</td>
<td>• Resp Rate High</td>
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<tr>
<td>• Extreme Tachy</td>
<td>• HR Limit Alarm</td>
<td></td>
<td>• Resp Rate Low</td>
</tr>
<tr>
<td>• Extreme Brady</td>
<td></td>
<td></td>
<td>• NBP High</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• NBP Low</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Pressure Lines High</td>
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<tr>
<td></td>
<td></td>
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<td>• Pressure Lines Low</td>
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Alarm Audit: 4 Units, ONE Day

Alarm Summary ~5000 Alarms/Day

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<tr>
<th>Unit</th>
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<th>8 patients</th>
<th>16 patients</th>
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<tr>
<td>4S</td>
<td>YELLOW BED</td>
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<tr>
<td></td>
<td>RED BED</td>
<td>60</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>YELLOW ARRHYTHMIA</td>
<td>1534</td>
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<tr>
<td>TICU</td>
<td>YELLOW BED</td>
<td>422</td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>RED BED</td>
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<td></td>
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<tr>
<td></td>
<td>YELLOW ARRHYTHMIA</td>
<td>444</td>
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<tr>
<td>MSICU</td>
<td>YELLOW BED</td>
<td>437</td>
<td></td>
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<tr>
<td></td>
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<td>YELLOW ARRHYTHMIA</td>
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<td>CCU</td>
<td>YELLOW BED</td>
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<td>RED BED</td>
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<td></td>
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<tr>
<td></td>
<td>RED ARRHYTHMIA</td>
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Alarm Fatigue Task Force: California Pacific Med Center

- Funding provided by internal Foundation Grant

- Group Members
  - Nursing Leaders: Jill Ley RN & Robert Airoso RN
  - Physician Champion: Rick Hongo, MD; Electrophysiology
  - Biomed Champion: Dale Rose
  - 22 Nurse Champions: staff nurses from all units
BASELINE: Determine Readiness for Change

- Questions developed by team leaders surrounding scope of problem, policies, and potential solutions
- 12 questions distributed to all RNs on monitored units via email; responses anonymous
- 95 responses indicated high degree of dissatisfaction & readiness for change
Alarm Management Strategy – 3 Campuses, 11 monitored units

- Baseline Philips audit of 4 units revealed high frequency of alarms and inconsistent practices.
- Detailed data from all 11 units obtained to formulate multidisciplinary approach including: nursing, physicians, biomed, administration.
- Phase 1: evidence based changes to monitor defaults; add high priority/RED alarm for leads off.
- Phase 2: changes in nursing practice disseminated through unit based Alarm Champions.
- Goal: create a safer culture of alarm management.
## Initial Variability in Default Alarm Settings

<table>
<thead>
<tr>
<th></th>
<th>TICU, TICU-3, STL tele</th>
<th>MSICU</th>
<th>CCU</th>
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<tr>
<td>High Limit</td>
<td>120</td>
<td>135</td>
<td>135</td>
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<tr>
<td>Low Limit</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
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<tr>
<td>Extreme Tachy Diff</td>
<td>20</td>
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<td>Tachy Clamp</td>
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<td>240</td>
<td>240</td>
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<tr>
<td>Extreme Brady Diff</td>
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<td>20</td>
<td>20</td>
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<tr>
<td>Brady Clamp</td>
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<td>50</td>
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<td>Asystole Thresh</td>
<td>4.0 SEC</td>
<td>4.0 SEC</td>
<td>4.0 SEC</td>
<td>4.0 SEC</td>
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<td>Vtach HR</td>
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<td>120</td>
<td>120</td>
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<td>Vtach Run</td>
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<td>10</td>
<td>10</td>
<td>10</td>
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<tr>
<td>Vent Rhythm</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
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<td>PVC's/min</td>
<td>10</td>
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<td>10</td>
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<td>Non-Sustain VT</td>
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<td>ON</td>
<td>ON</td>
<td>ON</td>
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<tr>
<td>V ent Rhythm</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
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<tr>
<td>Run PVC's</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
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<td>Pair PVC's</td>
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<td>V. Bigeminy</td>
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<td>ON</td>
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<td>V. Trigeminy</td>
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<td>PVCs/min</td>
<td>ON</td>
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<td>Pacer N. Pac</td>
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<td>Pause</td>
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<td>SVT</td>
<td>ON</td>
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<td>A-fib</td>
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Intensive Care Audit:
Most Frequent Yellow Arrhythmia Alarms

Non-Sustain Vtach
Vent Rhythm > 14
Run PVCs > 2
Pair PVCs
R on T PVC
Vent Bigem
Vent Trigem
PVC Rat > 10
Multiform PVC
Telemetry Audit: Most Frequent Red Arrhythmia Alarms

5S Red Arrhythmia Alarms: 42 patients

Predominantly HR deviations, some artifact
Alarm Management

Scope and Impact of the Problem

Alarm fatigue develops when a person is exposed to an excessive number of alarms. This situation can result in sensory overload, which may cause the person to become desensitized to the alarms. Consequently, the response to alarms may be delayed, or alarms may be ignored.
Recommendation: Implement Johns-Hopkins Best Practices to Remove “Nonactionable” Yellow and Redundant Alarms

**Predict 65% REDUCTION IN ALARMS** by eliminating:
- PVC pairs
- Multiform PVCs
- Run PVCs
- Bigeminy

Also eliminate redundant alarms.
SpO2 Low Limit Alarm: 472 Total in ICU

Reduce SpO2 Low Limit to < 88%

SpO2 Values Day 1
- 89: 47
- 88: 44
- 87: 43
- 86: 32
- 85: 38
- 84: 22
- 83: 15
- 82: 21
- 81: 17
- 80: 13
- 70-79: 9
- 60-69: 6
- <60: 6

SpO2 Values Day 2
- 89: 43
- 88: 33
- 87: 32
- 86: 22
- 85: 15
- 84: 8
- 83: 6
- 82: 6
- 81: 4
- 80: 5
- 70-79: 19
- 60-69: 13
- <60: 15
Phase 1: Implement Johns-Hopkins Best Practices

Remove “Nonactionable” Yellow Alarms

- Remove "Nonactionable" Yellow Alarms
- Additional A Fib Alarm
- Also eliminate redundant alarms
- Standardize HR defaults to 135, 50 and SpO2 to 88%
Phase 2: Change the Culture of Monitoring

- Electrode management
  - Skin prep
  - Change frequency
  - Lead placement

- Alarm settings to be reviewed at handoff
  - Adjust HR within 5-20 bpm from default as appropriate to pt condition
  - *Disable* irregular HR alarm for chronic AF (no order required)
  - *Enable* paced rhythm alarm for paced patients (no order required)

- Assume any alarm is now “actionable”

Eliminate false alarms from artifact
Figure 15. ECG signal quality in 12,671 annotated arrhythmia alarms.

http://www.plosone.org/article/info:doi/10.1371/journal.pone.0110274
Evidence-Based Electrode Management

AACN PracticeAlert

Alarm Management

Expected Practice and Nursing Actions*

- Provide proper skin preparation for ECG electrodes. (Level B)
  - Wash the isolated electrode area with soap and water, wipe the electrode area with a rough washcloth or gauze, and/or use the sandpaper on the electrode to roughen a small area of the skin.
  - Do not use alcohol for skin preparation; it can dry out the skin.

- Change ECG electrodes daily. (Level E)
  - Change daily or more often if needed.

New Standards: Focus on Lead Placement

http://www.plosone.org/article/info:doi/10.1371/journal.pone.0110274
Nursing Education: 4-hour Class for Alarm Champions

- Data review: results from 11 units
  - Proposed revisions to nursing policy

- Lecture: Improving the effectiveness of ECG monitoring
  - Barbara Drew RN, PhD, FAAN

- “Hands on” with Philips monitors
  - Troubleshoot waveforms and artifact
  - Make approved changes to settings

- Educational strategies and roll out plans
  - Work in pairs on units to educate peers
  - Weekly check-in and feedback via email
RESULTS: Yellow Alarms/Patient Day Reduced 57-89% Per Unit

Overall Reduction 77%
From 9515 alarms/146 pts to 1901 alarms/130 pts
RESULTS: Press-Ganey Patient Satisfaction Scores Regarding Noise

Mean Trends

Inpatient - 4 South
California Pacific Medical Center
Question - Noise level in and around room

Satisfaction Level

<table>
<thead>
<tr>
<th>Month</th>
<th>Value</th>
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<tr>
<td>May '13</td>
<td>66.8</td>
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<td>May '14</td>
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Mean 62.8

4 South
Project Implementation
Additional Solutions: Criteria for Telemetry

Do we NEED to monitor everyone?
Potential Adverse Consequences of ECG Monitoring

- Alarm fatigue!
- Resource utilization
  - Nursing hours and ratios
  - Disposables
  - Equipment maintenance and upkeep
- Reduced mobility for the patient
  - Increased time in bed
  - Potential delirium, pneumonia, etc.
- Patient & family concerns of being “critically ill”
- Misinterpretation of artifact as VT
Artifact Mimicking Ventricular Tachycardia

This patient was treated with lidocaine


Drew showed that 86.8% of VT alarms are FALSE!
Class I Criteria for Telemetry Monitoring

*Indicated for nearly all patients acutely*

- Potential for ischemia
  - Acute coronary syndromes/rule out MI
  - Hi risk CAD lesions awaiting intervention
- Potential for arrhythmia
  - Overdose/poisoning - drugs with arrhythmic toxicity
  - Antiarrhythmic loading (types I or III with potential pro-arrhythmia)
  - Recent cardiac arrest
  - With temporary pacer or pads
  - AICD or pacemaker implant and device-dependent
  - Mobitz type II or greater; new LBBB with acute MI
  - Long QT or other unstable arrhythmia
- Procedure-related or critically ill
  - Following cardiac surgery, PCI with complications
  - Acute HF, pulmonary edema, IABP
  - Undergoing procedure requiring conscious sedation or anesthesia

Class II Criteria for Telemetry Monitoring

*Indicated for some patients*

- **Potential for instability**
  - Chest pain syndromes
  - At risk for cardiac or respiratory arrest or hypotension
  - Receiving antiarrhythmic meds requiring adjustment (chronic condition)
  - Suspected/proven destabilizing PSVT or bradyarrhythmia
  - Subacute HF or acute pericarditis
  - Unexplained syncope or neuro event
  - Nonurgent, uncomplicated PCI or ablation
  - Symptomatic arrhythmia with DNR orders

- **Post event monitoring parameters**
  - > 3 days after AMI
  - >2-3 days after lethal arrhythmia *controlled*
  - >2-3 days after pacemaker implanted if *not* pacer dependent
  - For stable patients after routine cardiac surgery

Class III Criteria for Telemetry Monitoring

*Monitoring is NOT indicated*

- Acute conditions
  - Low risk post surgery
  - During labor and delivery without significant medical conditions
  - With terminal illness who are not candidates for treatment
  - Atypical chest pain with normal/non-specific EKG
- Chronic, stable conditions
  - Atrial fibrillation
  - Asymptomatic PVCs or non-sustained VT
  - Cardiac disease without significant arrhythmia x 3 days

Table 9. Key Insights into the Problem of Alarm Fatigue and Recommendations.

<table>
<thead>
<tr>
<th>Conditions Causing Excessive Alarms</th>
<th>Suggestions for Device Improvements</th>
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<tbody>
<tr>
<td>1. Alarms are not tailored to the individual patient</td>
<td>• Have monitor prompt more appropriate alarm settings; e.g., “Mean HR = 130; do you want to increase high HR setting?”</td>
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<td>2. Persistent atrial fibrillation</td>
<td>• Have monitor trigger alarms only upon new onset or termination of atrial fibrillation</td>
</tr>
<tr>
<td>3. Artifact mimics VT or VFib</td>
<td>• Have arrhythmia algorithm use all available ECG leads to identify a non-artifact lead</td>
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<td></td>
<td>• Make it easy to view and print out all available ECG leads at the time the alarm was triggered</td>
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<tr>
<td>7. Electrode failure causes poor signal quality</td>
<td>• Use VT rate, invasive arterial pressure and SpO2 to identify hemodynamically significant (symptomatic) VT</td>
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<tr>
<td>8. ST-segment alarms are not truly indicative of myocardial Ischemia</td>
<td>• Have monitor measure each electrode’s impedance and indicate when one is failing so electrode can be changed</td>
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<tr>
<td></td>
<td>• Make ST alarm delays configurable according to criteria for ischemia (lasting 1 minute) to prevent brief “spikes” in ST amplitude from triggering alarms</td>
</tr>
<tr>
<td>9. Flat-line respiratory waveform cause false apnea &amp; RR alarms</td>
<td>• Define ischemia only when present in 2 contiguous limb leads in order of aVL, I, minus aVR, II, aVF, III</td>
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<tr>
<td></td>
<td>• Have monitor automatically search for best available ECG lead to measure/display respiration waveform</td>
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<tr>
<td></td>
<td>• Investigate ECG-derived respiratory measurement to replace impedance method</td>
</tr>
</tbody>
</table>

Figure 4. True positive ventricular tachycardia alarm using seven available ECG leads for diagnosis.


http://www.plosone.org/article/info:doi/10.1371/journal.pone.0110274
Figure 6. **False positive ventricular tachycardia** alarm using seven available ECG leads for diagnosis.


[Link to the full article](http://www.plosone.org/article/info:doi/10.1371/journal.pone.0110274)
Alarm Fatigue Summary

- Alarm fatigue is an important problem that creates safety risks, as well as patient and nurse dissatisfaction

- Use of internal alarm data is essential to target highest priority alarms and improve outcomes

- Implementation of evidence-based practices is effective in reducing nuisance alarms while improving safety

- Technological changes are needed to truly achieve BEST practices in alarm management

▪ Ver Hage A. Alarm fatigue can endanger patients. Nurse.com; Feb 2014.

▪ Welch J. An evidence-based approach to reduce nuisance alarms and alarm fatigue. Horizons; Spring 2011.