Battling Alarm Fatigue

Tips from the trenches

Barbara J. Drew, RN, PhD, FAAN

ECG Monitoring Research Lab, UCSF School of Nursing
The wake-up call that changed hospitals forever…

- Male recovering from heart surgery (Mass General Hospital, Boston); monitored on a telemetry unit while waiting for surgery to implant a permanent pacemaker
- Patient ate breakfast, visited with family, walked around the unit, took a bath
- 9:53 am: low HR alarms sounded repeatedly; 10 RNs working on the unit that morning did not recall hearing those alarms
- 10:00 am: HR dropped below 40 but crisis level arrhythmia alarm did not sound because alarm had been changed to non-audible message alarm by someone on the night shift
- 10:16 am: Patient found dead
Investigators for the Centers for Medicare & Medicaid Services:

“Changing audible arrhythmia alarms to inaudible & nurses not recalling hearing low HR alarms are indicative of *alarm fatigue* which contributed to the patient’s death.”

Front page of the Boston Globe newspaper; multiple press stories on radio/TV

Hospital settled lawsuit before it went to trial for $850,000

Every hospital administrator: “Could this happen here?”
Could this happen at UCSF?

Monitor sound speakers turned to the wall

Please contact your Biomedical dept immediately; external speaker is unplugged.
GE & Drew Lab meeting about Alarm Fatigue at UCSF in April, 2012
UCSF Alarm Study
October, 2013-March, 2014

Study Units:
1. 8 NICU
2. 9 ICU
3. 10 ICC
4. 11 NICU
5. 13 ICU
Total, 77 adult ICU beds

All physiologic waveforms, measurements, alarm settings, & alarms for all patients (waiver of consent)

Funded by GE Healthcare
UCSF Alarm Study

77 Physiologic Monitors in 5 adult ICUs

CARESCAPE MC Network

CARESCAPE IX Network

Special research version CareScape Gateway

IX Router & Firewall

Hospital enterprise network

BedMaster Client

BedMasterEx

Alarm Event Router

VPN LINK
Goals of this presentation:

- Report alarm prevalence & types
- Provide tips to determine whether an arrhythmia alarm is true or false
- List strategies to reduce alarms
- Report findings from a RCT to test the effect of nursing interventions in reducing the alarm fatigue problem
GE Physiologic Monitor Alarm Categories

PATIENT STATUS ALARMS
(Something wrong with the patient)

- CRISIS
- WARNING
- ADVISORY
- MESSAGE

Arrhythmia detected

Alarms
- ASYSTOLE
- VFIB/VTAC
- VTACH
- ACC VENT
- PAUSE
- VBRADY
- AFIB
- VT>2
- BRADY
- TACHY
- BIGEMINY
- TRIGEMINY
- COUPLETT
- R on T

Parameter violation (too low / too high)

Alarms
- HR
- RR
- SPO2
- NBP
  Systolic, diastolic, mean
- ART
- ICP
  Systolic, diastolic, mean
- PA
- CVP
- PVCs
  ST ALARM
  NO BREATH/APNEA

SYSTEM STATUS ALARMS
(Something wrong with the electrodes, SpO₂ sensor)

- WARNING
- Fog-horn tone

- ADVISORY
  Alarm Text
  Flashing text

Alarms
- ARTIFACT
- ARRHY SUSPEND
- ARR OFF
- LEADS FAIL
- ALARM PAUSE
- ALL ALARMS OFF
- NO ECG
- SPO2 SENSOR
- RR LEADS FAIL
How many alarms occurred in the 31 days of March in our 5 adult ICUs (77 beds)?

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Alarms</td>
<td>2,507,822</td>
</tr>
<tr>
<td>Arrhythmia</td>
<td>1,050,226</td>
</tr>
<tr>
<td>Parameter (too hi; too low)</td>
<td>665,136</td>
</tr>
<tr>
<td>Technical (signal problem)</td>
<td>792,460</td>
</tr>
<tr>
<td>Audible Alarms</td>
<td>381,560</td>
</tr>
<tr>
<td>Audible Alarm Burden</td>
<td>178 alarms/bed/day</td>
</tr>
</tbody>
</table>
Tips to determine whether an arrhythmia alarm is true or false
Tip #1
Print out all available ECG leads

If it is a false alarm due to motion artifact, there is often a lead without artifact that identifies the rhythm.
Standard 5-Electrode Lead Configuration

7 available leads:
- 6 limb leads (I, II, III, aVR, aVL, aVF)
- 1 precordial lead (V)

ECG Monitoring Research Lab, UCSF School of Nursing
≥6 consecutive PVCs ≥100 bpm

False alarm due to artifact
False alarm due to artifact
Tip #2

Evaluate effect of alarm on arterial pressure & SpO2 waveforms
Same Alarm…

Immediate drop in arterial pressure

TRUE Alarm
False alarm due to artifact

1. Does rate of pressure or SpO₂ waveforms match the possible VT or normal rate?
2. Is there a drop in arterial pressure with event?

Assess Art & SpO₂:

Non-artifact Lead
What 4 criteria indicate this is a false alarm?

1. Non-artifact Lead shows SR, not VT
2. Arterial waveform matches normal rate, not the possible VT
3. SpO₂ waveform matches normal rate, not the possible VT
4. No drop in arterial pressure

Summary
Tip #3
Make sure the ventricular alarm is not a normal or supraventricular rhythm with bundle branch block.

If an arrhythmia alarm has the same QRS morphology in all 7 available leads as the patient’s normal rhythm with BBB, it isn’t a ventricular rhythm.
Sinus rhythm with LBBB

VTACH Alarm

Atrial fib with LBBB
Strategies to Reduce Alarm Fatigue

Tip #1
Tailor alarm limit settings to your individual patient
Patient with atrial fibrillation

Hospital default setting = HR >130 sounds high HR alarm

While treatment is underway to restore sinus rhythm, the nurse should ↑ the alarm limit to >150 to prevent repetitive high HR alarms & reduce alarm fatigue
Strategies to Reduce Alarm Fatigue

Tip #2
Change non-actionable alarms to message (inaudible) for individual patients
Monitor Default Settings for Adult ICUs

“One size does not fit all”

<table>
<thead>
<tr>
<th>Arrhythmia Alarm Levels</th>
<th>Crisis</th>
<th>Warning</th>
<th>Advisory</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asystole</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vfib/Vtac</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V Tach (&gt;5 pvcs)</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>VT &gt;2 (2-5 pvcs)</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V Brady</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Couplet</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Bigeminy</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Acc Vent</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Pause</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Trigeminy</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>R on T</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>PVC</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Tachy</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Brady</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Afib</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

ECG Monitoring Research Lab, UCSF School of Nursing
Patient with atrial fibrillation

A ton of parameter (HR >130) + AFIB alarms would have been avoided if the nurse had tailored alarms for this patient!
Strategies to Reduce Alarm Fatigue

Tip #3
Use practice guidelines to define hospital default settings
ACUTE MANAGEMENT OF VTACH (in-hospital):

“Neither accelerated ventricular rhythm nor non-sustained ventricular tachycardia (<30 seconds) warrant antiarrhythmic therapy. Only sustained &/or hemodynamically compromising VT requires treatment.”

Heart Rate = 55 bpm

Ventricular rhythm 50-100 bpm

TRUE Alarm
True ACC VENT alarm rarely causes fall in arterial pressure so doesn’t require treatment (non-actionable alarm)

No difference in arterial pressure between accelerated ventricular rhythm and normal rhythm
## Monitor Default Settings for Adult ICUs

### Arrhythmia Alarm Levels

<table>
<thead>
<tr>
<th>Condition</th>
<th>Crisis</th>
<th>Warning</th>
<th>Advisory</th>
<th>Message</th>
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<tbody>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>VT &gt;2 (2-5 pvcs)</td>
<td></td>
<td></td>
<td>x</td>
<td>&gt;11,000/month</td>
</tr>
<tr>
<td>V Brady</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Couplet</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Bigeminy</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Acc Vent</td>
<td></td>
<td>x</td>
<td></td>
<td>&gt;3,000/month</td>
</tr>
<tr>
<td>Pause</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Trigeminy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R on T</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>PVC</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Tachy</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Brady</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Irregular (R-R)</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Afib</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>

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Case Example: Patient with RBBB who was monitored for 17 days in the ICU

<table>
<thead>
<tr>
<th>Ventricular Alarms</th>
<th># False Alarms</th>
</tr>
</thead>
<tbody>
<tr>
<td>VBRADY</td>
<td>14</td>
</tr>
<tr>
<td>ACC VENT</td>
<td>41</td>
</tr>
<tr>
<td>VT&gt;2</td>
<td>1,700</td>
</tr>
<tr>
<td>VTACH</td>
<td>1,129</td>
</tr>
<tr>
<td>TOTAL:</td>
<td>2,884</td>
</tr>
</tbody>
</table>

Would the nurse be justified in permanently silencing these alarms to allow the patient to rest?
What could have been done to reduce alarm fatigue while still keeping this patient safe?

<table>
<thead>
<tr>
<th>Ventricular Alarms</th>
<th># Alarms</th>
<th>New # Alarms</th>
</tr>
</thead>
<tbody>
<tr>
<td>VBRADY</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>ACC VENT</td>
<td>132</td>
<td>0</td>
</tr>
<tr>
<td>VT &gt; 2</td>
<td>1,700</td>
<td>0</td>
</tr>
<tr>
<td>VTACH</td>
<td>1,130</td>
<td>1,130</td>
</tr>
<tr>
<td><strong>TOTAL:</strong></td>
<td>2,976</td>
<td><strong>1,144</strong></td>
</tr>
</tbody>
</table>

62% reduction in alarms
Strategies to Reduce Alarm Fatigue

Tip #4
Add alarm delays when possible for selected parameter alarms (too high / too low alarms)
ST alarms in 16-bed Cardiac ICU in March, 2013

N=6,196 or 200 ST alarms/day

<table>
<thead>
<tr>
<th>Alarm Duration (seconds)</th>
<th>Number of Events</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 &lt; 30</td>
<td>4981</td>
<td>80%</td>
</tr>
<tr>
<td>30 &lt; 60</td>
<td>673</td>
<td>11%</td>
</tr>
<tr>
<td>&gt; 60</td>
<td>542</td>
<td>9%</td>
</tr>
<tr>
<td>TOTAL:</td>
<td>6196</td>
<td></td>
</tr>
</tbody>
</table>

1 minute alarm delay would ↓ST alarms by 91%
False Alarm due to electrode problem
Electrodes exposed to air causes the gel to deteriorate resulting in poor quality ECGs and ↑↑↑↑ false alarms.
Effect of Nursing Interventions on Physiologic Monitor Alarm Rates in a Neuroscience Intensive Care Unit

Funded by the American Association of Critical-Care Nurses and GE Healthcare

Tina Mammone, RN, PhD
### Research Design

#### 1st prospective, randomized clinical trial

<table>
<thead>
<tr>
<th></th>
<th>Assessment 1</th>
<th>Assessment 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>31-days, March, 2013</td>
<td>31-days, August, 2013</td>
</tr>
<tr>
<td>Control Unit</td>
<td>Usual Care</td>
<td>Usual Care</td>
</tr>
<tr>
<td>Experimental Unit</td>
<td>Usual Care</td>
<td>• Optimal ECG Electrode Regimen</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Modified SpO$_2$ Alarm Settings</td>
</tr>
</tbody>
</table>
I. Technology-based Intervention

Modification of default SpO$_2$ alarm setting

Control Unit

Default SpO$_2$ alarm settings

- SpO$_2$ low-limit threshold alarm setting ($\leq 90\%$)
- 5-sec SpO$_2$ alarm delay

Experimental Unit

Default SpO$_2$ alarm settings

- SpO$_2$ low-limit threshold alarm setting ($\leq 88\%$)
- 15-sec SpO$_2$ alarm delay
Optimum electrode regimen

Control Unit
- Skin preparation: Usual care (typically, none)
- ECG electrodes: Change per usual care
  - Ag/AgCl ECG electrode-hydrogel

Experimental Unit
- Skin preparation: ECG skin prep paper
- ECG electrodes:
  - Change daily (4am-7am)
  - Ag/AgCl ECG electrode-pregelled, wet
II. Practice-based Intervention

Outcome variables to determine the value of the optimum electrode regimen:

**ECG Lead Fail Alarm**
- Quality of an electrode signal degrades to an inadequate level

**Artifact Alarm**
- Transient condition resulting from intermittent noise and artifact
- Full arrhythmia processing is suspended; however, lethal arrhythmia detection remains active

**Arrhythmia Alarms**
- Crisis, warning, & advisory level (audible) arrhythmia alarms (6)
II. Practice-based Intervention

Outcome variables (con’t)…

**Selected Arrhythmia Alarms for Annotation**

1. **ASYSTOLE**: HR drops to zero; typically no QRS for > 5-s
2. **VFIB/VTACH**: Course flutter waves without QRS complexes
3. **VTACH**: ≥6 consecutive ventricular beats at rate ≥100
4. **VBRADY**: ≥3 consecutive ventricular beats, average rate ≤50
5. **ACC VENT**: ≥6 ventricular beats, average HR between 50-100
6. **PAUSE**: No QRS for a 3-s interval
Results

I. Modification of SpO$_2$ Alarm Setting
Reduced alarms

**SpO₂ Low-limit Threshold Alarm**

![Bar chart showing mean hourly rate for SpO₂ low-limit alarm with p-values]

- Control Unit Assessment 1 (n=89): 0.81
- Control Unit Assessment 2 (n=96): 0.91
- Experimental Unit Assessment 1 (n=124): 0.85
- Experimental Unit Assessment 2 (n=120): 0.30

*p = .69*

*p < .001*
Results - *Is it safe?*

I. Modification of SpO\textsubscript{2} Alarm Setting

No significant differences in the incidence of adverse patient events during 6 months preceding & after SpO2 threshold changes
Results

II. Optimum Electrode Regimen
No Effect
Artificial Alarm

No Effect
II. Optimum Electrode Regimen

No reduction in mean percentage of false-positive alarms occurred in the experimental unit during Assessment 2.
Conclusions

- A lower SpO₂ alarm limit in combination with an alarm delay safely reduces non-actionable SpO₂ alarms

- An optimal electrode regimen does not reduce technical nor false-positive arrhythmia alarms

  Can’t rely on clinical practice to be the cure-all for alarm fatigue

- Future studies are required to determine whether improved algorithms will reduce the high percentage of false-positive arrhythmia alarms
Tina presented her study at the International Society for Computerized Electrocardiology (ISCE) Annual Conference in Florida last week.

ASYSTOLE: The ultimate stable rhythm
Tina presented her study at the International Society for Computerized Electrocardiology (ISCE) Annual Conference in Florida last week.
Unlike Mass General Hospital, UCSF got good press related to alarm fatigue.
We made the front page!

Thank You!

ECG Monitoring Research Lab, UCSF School of Nursing