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Disclosure

Faculty Disclosure
Maria Cvach, RN, MS, CCRN has disclosed no relevant, real or apparent personal or professional financial relationships.

Marjorie Funk, PhD, RN, FAHA, FAAN has disclosed that she receives research support from Philips Healthcare. She is also on the Speaker’s Bureau of Philips Healthcare and GE Healthcare and serves as a Consultant for GE Healthcare.

Acknowledgement of Commercial Support
There was no commercial support received for this CME activity
Learning Objectives

1. Define the problem and implications of alarm fatigue for caregivers and patients.

2. Identify best practice strategies to reduce alarm fatigue.

3. State three methods to assure secondary alarm notification.

4. Specify four recommendations for the design of future research on monitor alarm fatigue.
NPSF Professional Learning Series presents:

Monitor Alarm Fatigue: Lessons Learned

July 16, 2012

Maria Cvach, RN, MSN, CCRN
Marjorie Funk, RN, PhD
Purpose of Clinical Alarms

- Enhance patient safety
  - Patient deteriorating
  - Device not functioning

- Perfect alarm system
  - Never miss a clinically important event (100% sensitivity)
  - Never alarm when there is no clinically important event (100% specificity)

- High sensitivity & low specificity → many false alarms → alarm fatigue
Cacophony of Alarm Sounds

Infusion Pump
Monitor
Ventilator
Bed Exit

CRRT Pump
Wound VAC
IABP Pump
Feeding Pump

SCD
Alarm Fatigue

- Staff become overwhelmed by the sheer number of alarms →
- Alarm desensitization →
- Missed alarms or delayed response to alarms

Crying Wolf

> 90% of alarms are false

Aesop
“Asystole”???
Alarm Hazards

- Alarms ignored or deactivated → patient deaths
- Alarm hazards → #1 of Top 10 Technology Hazards for 2012 (ECRI Institute)
- Systematic strategy to address alarm fatigue (FDA & The Joint Commission)
“A Massachusetts General Hospital patient died last month after the alarm on a heart monitor was inadvertently left off, delaying the response of nurses and doctors to the patient’s medical crisis.”  
(Kowalczyk, 2-21-10)

- # of deaths linked to monitor alarms
  - 2005-2010: 216 deaths (Kowalczyk, 2-13-11)
  - 2005-2008: 566 deaths (FDA, 2009)

- Goal: “No patient will be harmed by adverse alarm events.”
  
(Logan, AAMI 2011 Alarm Summit)
Monitor Alarms: New Approaches and Best Practices

Maria Cvach, RN, MS, CCRN
Assistant Director of Nursing
Johns Hopkins Hospital
CUSP Team
Interdisciplinary Monitor Alarm Committee

Nursing
Clinical Engineering and IT
Physicians
Human Factors
Respiratory Therapy

Support from Hospital Administration
Missed Alarm
Fault Tree Analysis
Alarm Assessment:
Sample 12 Day Alarm Analysis

<table>
<thead>
<tr>
<th>Priority</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crisis - 0</td>
<td>1587</td>
</tr>
<tr>
<td>Warning - 1</td>
<td>6673</td>
</tr>
<tr>
<td>Advisory - 2</td>
<td>48277</td>
</tr>
<tr>
<td>System Warning - 3</td>
<td>2227</td>
</tr>
<tr>
<td>Grand Total of Alarms</td>
<td>58764</td>
</tr>
<tr>
<td>Ave Bed Census</td>
<td>14</td>
</tr>
<tr>
<td>Ave Alarms/Bed/Day</td>
<td>350</td>
</tr>
</tbody>
</table>
### TABLE 2

<table>
<thead>
<tr>
<th>Condition</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASYSTOLE</td>
<td>CRISIS</td>
</tr>
<tr>
<td>VFIB/VTAC</td>
<td>CRISIS</td>
</tr>
<tr>
<td>V TACH</td>
<td>CRISIS</td>
</tr>
<tr>
<td>VT &gt; 2</td>
<td>CRISIS - Message</td>
</tr>
<tr>
<td>V BRADY</td>
<td>CRISIS</td>
</tr>
<tr>
<td>COUPLET</td>
<td>WARNING - Message</td>
</tr>
<tr>
<td>BIGEMINY</td>
<td>WARNING - Message</td>
</tr>
<tr>
<td>ACC VENT</td>
<td>MESSAGE</td>
</tr>
<tr>
<td>PAUSE</td>
<td>WARNING - Message</td>
</tr>
<tr>
<td>TRIGEMINY</td>
<td>ADVISORY - Message</td>
</tr>
<tr>
<td>R ON T</td>
<td>MESSAGE</td>
</tr>
<tr>
<td>PVC</td>
<td>MESSAGE</td>
</tr>
<tr>
<td>TACHY</td>
<td>WARNING - Message</td>
</tr>
<tr>
<td>BRADY</td>
<td>WARNING - Message</td>
</tr>
<tr>
<td>IRREGULAR</td>
<td>MESSAGE</td>
</tr>
<tr>
<td>HR</td>
<td>WARNING (limits 50 and 115 - 120)</td>
</tr>
<tr>
<td>PVC</td>
<td>ADVISORY - Message</td>
</tr>
<tr>
<td>ST</td>
<td>ADVISORY - Message (limits changed from -1 and 1 to -2 and 2)</td>
</tr>
<tr>
<td>ART</td>
<td>ADVISORY (limits Sys H-180 L-90; Mean H - 120 Lo-55; Dia H-110 Lo 40)</td>
</tr>
<tr>
<td>SPO2</td>
<td>ADVISORY (Limit - 89)</td>
</tr>
</tbody>
</table>

---

**Modest default parameter changes:**

- Standardized
- Actionable alarms
- Visual alarm vs audible alarm
- Parameter limits adjusted
<table>
<thead>
<tr>
<th>Priority</th>
<th>ICU A Quantity 7 day Pre Default June 2010</th>
<th>ICU A Quantity 7 day Post Default December 2010</th>
<th>ICU B Quantity 7 day Pre Default June 2010</th>
<th>ICU B Quantity Post Default Dec 2010</th>
<th>IMC Quantity 12 day Pre Default April 2010</th>
<th>IMC Quantity 12 day Post Default Jan/Feb 2011</th>
<th>ICUC Quantity 12 day Pre Default April 2010</th>
<th>ICUC Quantity 12 day Post Default April 2011</th>
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</thead>
<tbody>
<tr>
<td>Grand Total of Alarms</td>
<td>29844</td>
<td>18050</td>
<td>86317</td>
<td>38382</td>
<td>94600</td>
<td>24252</td>
<td>38662</td>
<td>23096</td>
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<tr>
<td>Ave Pt Census</td>
<td>13</td>
<td>13</td>
<td>16</td>
<td>13</td>
<td>14</td>
<td>14</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>Ave Alarms/Bed/Day</td>
<td>317</td>
<td>203</td>
<td>771</td>
<td>431</td>
<td>563</td>
<td>144</td>
<td>251</td>
<td>145</td>
</tr>
<tr>
<td>% reduction</td>
<td>36%</td>
<td>44%</td>
<td>74%</td>
<td></td>
<td>42%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave Alarms/Bed/Day Crises</td>
<td>2</td>
<td>0.8</td>
<td>1</td>
<td>0.3</td>
<td>5</td>
<td>6</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Ave Alarms/Bed/Day Warning</td>
<td>33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave Alarms/Bed/Day Advisory</td>
<td>245</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ave Alarms/Bed/Day System Warnings</td>
<td>37</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SYSTEM WARNING-3</td>
<td>ICUA PRE</td>
<td>ICUA POST</td>
<td>ICUB PRE</td>
<td>ICUB POST</td>
<td>IMCA PRE</td>
<td>IMCA POST</td>
<td>ICUC PRE</td>
<td>ICUC POST</td>
</tr>
<tr>
<td>------------------</td>
<td>----------</td>
<td>-----------</td>
<td>----------</td>
<td>-----------</td>
<td>----------</td>
<td>-----------</td>
<td>----------</td>
<td>-----------</td>
</tr>
<tr>
<td>TOTAL</td>
<td>3514</td>
<td>3704</td>
<td>1699</td>
<td>3561</td>
<td>2485</td>
<td>2445</td>
<td>2130</td>
<td>2575</td>
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<tr>
<td>PERCENT CHANGE</td>
<td>5%</td>
<td>109%</td>
<td>-1.6%</td>
<td>21%</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>ARRHY SUSPEND</td>
<td>432</td>
<td>135.29%</td>
<td>152</td>
<td>8.95%</td>
<td>110</td>
<td>3.09%</td>
<td>732</td>
<td>29.46%</td>
</tr>
<tr>
<td>LEADS FAIL</td>
<td>270</td>
<td>7.68%</td>
<td>582</td>
<td>15.71%</td>
<td>172</td>
<td>10.12%</td>
<td>289</td>
<td>8.12%</td>
</tr>
<tr>
<td>RR LEADS FAIL</td>
<td>261</td>
<td>7.43%</td>
<td>534</td>
<td>14.42%</td>
<td>226</td>
<td>13.3%</td>
<td>417</td>
<td>11.71%</td>
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<tr>
<td>NBP FAIL</td>
<td>55</td>
<td>1.57%</td>
<td>19</td>
<td>0.51%</td>
<td>7</td>
<td>0.41%</td>
<td>57</td>
<td>2.29%</td>
</tr>
<tr>
<td>NBP MAX TIME</td>
<td>1</td>
<td>.01%</td>
<td>6</td>
<td>.16%</td>
<td>57</td>
<td>2.99%</td>
<td>14</td>
<td>1.1%</td>
</tr>
<tr>
<td>NBP OVER PRES</td>
<td>2</td>
<td>.04%</td>
<td>63</td>
<td>2.58%</td>
<td>80</td>
<td>3.76%</td>
<td>40</td>
<td>1.55%</td>
</tr>
<tr>
<td>SENSOR</td>
<td>2</td>
<td>.04%</td>
<td>64</td>
<td>2.58%</td>
<td>80</td>
<td>3.76%</td>
<td>40</td>
<td>1.55%</td>
</tr>
<tr>
<td>SPO2 PROBE</td>
<td>2</td>
<td>.04%</td>
<td>64</td>
<td>2.58%</td>
<td>80</td>
<td>3.76%</td>
<td>40</td>
<td>1.55%</td>
</tr>
<tr>
<td>SPO2 SENSOR</td>
<td>2</td>
<td>.04%</td>
<td>64</td>
<td>2.58%</td>
<td>80</td>
<td>3.76%</td>
<td>40</td>
<td>1.55%</td>
</tr>
<tr>
<td>CHNGE BATTERY</td>
<td>1</td>
<td>.04%</td>
<td>64</td>
<td>2.58%</td>
<td>80</td>
<td>3.76%</td>
<td>40</td>
<td>1.55%</td>
</tr>
<tr>
<td>LF: NO TELEM</td>
<td>1</td>
<td>.04%</td>
<td>64</td>
<td>2.58%</td>
<td>80</td>
<td>3.76%</td>
<td>40</td>
<td>1.55%</td>
</tr>
<tr>
<td>NO TELE</td>
<td>1</td>
<td>.04%</td>
<td>64</td>
<td>2.58%</td>
<td>80</td>
<td>3.76%</td>
<td>40</td>
<td>1.55%</td>
</tr>
</tbody>
</table>

Technical alarms unchanged by default changes
### Daily electrode change pilot: July 2011

**MPC4 and CCU**

<table>
<thead>
<tr>
<th></th>
<th>MPCU Baseline</th>
<th>MPCU Daily Electrode Change</th>
<th>% change</th>
<th>CCU Baseline</th>
<th>CCU Daily Electrode Change</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average Alarms/Bed/Day</strong></td>
<td>183</td>
<td>97</td>
<td>47% ↓</td>
<td>195</td>
<td>106</td>
<td>46% ↓</td>
</tr>
<tr>
<td><strong>Average Alarms/Bed/Day Crisis Alarms</strong></td>
<td>6.4</td>
<td>6</td>
<td>6% ↓</td>
<td>3</td>
<td>3</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Average Alarms/Bed/Day Warning Alarms</strong></td>
<td>49</td>
<td>26</td>
<td>47% ↓</td>
<td>18</td>
<td>10</td>
<td>44% ↓</td>
</tr>
<tr>
<td><strong>Average Alarms/Bed/Day Advisory Alarms</strong></td>
<td>113</td>
<td>54</td>
<td>52% ↓</td>
<td>162</td>
<td>87</td>
<td>46% ↓</td>
</tr>
<tr>
<td><strong>Average Alarms/Bed/Day System Warning Technical Alarms</strong></td>
<td>15</td>
<td>10</td>
<td>34% ↓</td>
<td>11</td>
<td>6</td>
<td>45% ↓</td>
</tr>
</tbody>
</table>
Alarm Notification

How do you get alarm information to the caregiver?

Weekly Alarm Management Committee
Primary Alarm Notification

Central Monitor

Patient

Bedside Monitor
Secondary Alarm Notification

Monitor watch

Split bedside Screens

Waveform Screens

Phones

Pagers

View on alarm
<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Total Alarms Delay &lt;10</th>
<th>Total Alarms Delay &lt;15</th>
<th>Total Alarms Delay &lt;30</th>
<th>Total Alarms Delay &lt;60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crisis-0</td>
<td>585</td>
<td>437</td>
<td>230</td>
<td>222</td>
<td>24</td>
</tr>
<tr>
<td>Warning-1</td>
<td>4731</td>
<td>3609</td>
<td>1567</td>
<td>635</td>
<td>247</td>
</tr>
<tr>
<td>System Warning-3</td>
<td>2575</td>
<td>1967</td>
<td>1526</td>
<td>920</td>
<td>417</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>7891</strong></td>
<td><strong>6013</strong></td>
<td><strong>3323</strong></td>
<td><strong>1777</strong></td>
<td><strong>688</strong></td>
</tr>
<tr>
<td>Census</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>All Al/pt/day</td>
<td>359</td>
<td>273</td>
<td>151</td>
<td>81</td>
<td>31</td>
</tr>
<tr>
<td>Ave Alarms/Pt/Day Crises</td>
<td>2</td>
<td>23</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Ave Alarms/Pt/Day Warning</td>
<td>18</td>
<td>14</td>
<td>6</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Ave Alarms/Pt/Day System Warning</td>
<td>10</td>
<td>7</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

Crises alarms sent immediately to nurse; Warning and system warning alarms sent after a 60 second delay to allow for auto correction or staff in room to silence.
Notification of active physiological alarms will escalate until the condition is cleared. Acknowledging alarms delays the escalation process which can only be stopped by correcting the alarm condition, silencing the alarm or activating “Alarm Pause” on the bedside monitor.

Alarm escalation via middleware

***System warning alarms include:***
- Arrhythmia Suspend
- Leads Fail
- Leads fail no telem
- No telem
- RR Leads Fail
- Change Battery
Alarm Notification

- Middleware - routes alarm to specific devices
  - Pagers or phones
    - Alarm escalation and alarm delays possible
Clinical Research on Alarms

Marjorie Funk, RN, PHD
Professor
Yale School of Nursing
Overview

- What do we know?
- What do we still not know?
- What are priorities for future research?
Existing Research: What Do We Know?

What is currently happening with alarms on hospital units?

1. Surveys of users
2. Retrospective analyses of alarm events on hospital units
3. Observation of alarms & practices on hospital units

No RCTs!
Alarms: Opinions of Users

- Dissatisfied with current alarm systems re: alarm frequency & specificity (Siebig et al, 2009)
- Priority issues (Korniewicz et al, 2008; HTF, 2011):
  1. ↓ nuisance alarms: → alarm fatigue & adverse events
  2. Alarm sounds / visual displays: should be distinct based on parameter or source & differentiate priority of alarm
  3. “Smart” alarms advantageous
  4. Minority of hospitals: alarm improvement efforts
  5. Adverse events r/t alarms reported by 1 in 5 responders – not fully reported to FDA
<table>
<thead>
<tr>
<th>Source</th>
<th>Setting</th>
<th>Time-frame</th>
<th># Alarms</th>
<th># Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atzema et al, 2006</td>
<td>ED</td>
<td>371 hrs</td>
<td>1,762</td>
<td>11</td>
</tr>
<tr>
<td>Görges et al, 2009</td>
<td>MICU</td>
<td>200 hrs</td>
<td>1,214</td>
<td>64</td>
</tr>
<tr>
<td>Talley et al, 2011</td>
<td>PICU</td>
<td>45 days</td>
<td>2,245</td>
<td>68</td>
</tr>
<tr>
<td>Fidler et al, 2011</td>
<td>6 adult units</td>
<td>2 mos</td>
<td>318,009</td>
<td>19 Code Blues</td>
</tr>
</tbody>
</table>
Sources of Alarms in MICU

- Ventilator: 46%
- Monitor: 37%
- Infusion Pump: 12%
- Other: 5%

57% of alarms associated with patient care activities

Görges et al, 2009
Sources of Monitor Alarms

- ECG 83%
- Pulse Ox 14%
- Apnea 2%
- BP 1%

PVC alarms most frequent

Fidler et al, 2011
Reducing Alarms by Changing Settings

1. **Threshold**: reduce # of alarms by up to 75%
   - Gross et al, 2011
     - High HR: 120 to 130 → 50% reduction
     - Low SpO₂: 90% to 85% → 36% reduction
     - Low SpO₂: 90% to 80% → 65% reduction
   - Welch, 2011
     - Low SpO₂: 90% to 88% → 45% reduction
     - Low SpO₂: 90% to 85% → 75% reduction
2. **Delay**: reduce # of alarms by up to 70%
   - **Welch, 2011: SpO₂ alarms**
     - 5 sec delay → 32% decrease
     - 10 sec delay → 57% decrease
     - 15 sec delay → 70% decrease
   - **Görges et al, 2009: Ignored & ineffective alarms**
     - 14 sec delay → 51% decrease
     - 19 sec delay → 67% decrease

➢ Safe?
## False Alarms

<table>
<thead>
<tr>
<th>Source</th>
<th>Setting</th>
<th>% False Alarms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lawless, 1994</td>
<td>PICU</td>
<td>95%*</td>
</tr>
<tr>
<td>Tsien &amp; Facklet, 1997</td>
<td>PICU</td>
<td>86%</td>
</tr>
<tr>
<td>Chambrin et al, 1999</td>
<td>5 Adult ICUs</td>
<td>72%</td>
</tr>
<tr>
<td>Atzema et al, 2006</td>
<td>ED</td>
<td>99%</td>
</tr>
<tr>
<td>Görges et al, 2009</td>
<td>MICU</td>
<td>77%</td>
</tr>
<tr>
<td>Siebig et al, 2010</td>
<td>MICU</td>
<td>85%</td>
</tr>
</tbody>
</table>

*Includes false alarms & insignificant alarms induced by staff manipulation*
False Alarm Suppression Algorithm

False critical ECG alarms reduced from 43% to 17%

Aboukhalil et al, 2008
Quality Improvement Initiatives

- Johns Hopkins Hospital, Baltimore, MD
  - Cvach et al, 2011, Alarm Summit Poster: Daily electrode change

- Dartmouth Hitchcock Medical Center, Lebanon, NH

- William Beaumont Hospital, Detroit, MI

- Boston Medical Center, Boston, MA

- VA Boston Healthcare System, Boston, MA
What Do We Still Not Know?

• What’s the best way to increase specificity of alarms without a significant loss of sensitivity?

• Interventions to reduce false or non-actionable alarms have not been rigorously tested
Focus of Future Research

1. Reduce false alarms
2. Reduce non-actionable alarms
3. Avoid unnecessary monitoring
4. Improve equipment
5. Improve processes of care

➢ “Solution fatigue” (Wise, The Joint Commission)
Alarm Fatigue Due to False & Non-Actionable Alarms

- **False alarms** occur when there is no valid triggering event.
- **Non-actionable alarms** correctly sound, but for an event that has no clinical relevance.
1. Reduce False Alarms

A. Ensure good signal quality
   ▫ Good skin prep to ensure electrode adherence
   ▫ Change electrodes daily
   ▫ Good quality electrodes & lead wires

B. Central monitoring with monitor techs?

C. Context awareness, eg, silence alarms when doing pt care

D. Use “smart” monitors – consider other parameters before alarming or delay before alarming
2. Reduce **Non-Actionable Alarms**

A. Customize alarm settings to individual patient

B. Deactivate default alarms for conditions we don’t treat, eg, PVCs
3. Avoid Unnecessary Monitoring

- The more patients on monitors → the more alarms
- Invention does not have to be the mother of necessity
- AHA Practice Standards (Drew et al., 2004): who should be monitored & for how long
- Baseline PULSE Trial data (Funk, et al., 2010): 85% of 783 patients with no indication for monitoring were on a monitor
- Monitoring noninvasive → harmless?
4. Improve Equipment

• Better algorithms
  ▫ Incorporating delays before alarming
  ▫ Automatically customize alarm settings to individual patient

• Detection of artifact / false alarm suppression technology

• Best type of audible alarms or alternative approaches to audible alarms

• Alarm standardization?
5. Improve Processes of Care

- Approach to alarm notification
- Use of central monitoring with monitor techs
  - # of patients monitor techs can effectively watch
  - On-unit vs. remote area
  - Reduction in nurses’ ECG knowledge?
- Education of clinicians re: full capability of devices → quick reference
Design of Future Research

• Randomized clinical trials
• Comparative effectiveness trials
• Interdisciplinary: collaboration between industry / engineers & clinicians
• Multi-site studies
• Meaningful outcomes
  ▫ Focus on patient outcomes
  ▫ Potential problem with lack of statistical power for mortality / sentinel events
Conclusions

• Rigorous research designs
• Focus on patient outcomes: no patient harmed by decrease in alarms
Submit a Question

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