Daily Electrode Change and Effect on Cardiac Monitor Alarms
An Evidence-Based Practice Approach

Maria M. Cvach, MSN, RN, CCRN; Madalyn Biggs, BSN, RN, PCCN; Kathleen J. Rothwell, MSN, RN; Charmaine Charles-Hudson, MSN, RN, CNRN

Frequent monitor alarms are distracting and interfere with clinicians performing critical tasks. This article describes a quality improvement rapid-cycle change approach to explore the benefits of changing electrodes daily on the number of cardiac monitor alarms. Eight days of baseline and intervention data were compared for 2 adult acute care units. Average alarms per bed per day were reduced by 46% on both units. Daily electrocardiogram electrode change reduces the number of cardiac monitor alarms. Key words: alarms, cardiac monitor, ECG, electrode, evidence-based practice, noise, quality improvement

The myriad of medical device audible alarms has created an environment that poses significant risk to patient safety. The Emergency Care Research Institute, a non-profit organization that applies scientific research in health care to establish best practices for improving patient care, publishes an annual top-10 technology hazards list. Alarm hazards are the number 1 health technology hazard for 2012.1 Evidence indicates that frequent alarms are distracting and interfere with clinicians’ performance of critical tasks and may lead to errors of omission, inattention, or disabling of alarm systems by staff.2 Cardiac monitor alarms account for the majority of noise in intermediate and intensive care units. There are as many as 700 physiologic and cardiac monitor alarms per bed generated by monitors each day (M. Cvach, unpublished data, 2011). Alarm signals generate enough noise to hinder patient recovery. Staff conversation and alarms are regarded as the most disturbing noises causing sleep deprivation in the intensive care unit.3 Sleep disturbance is a factor in the development of delirium as well as producing effects on the respiratory, cardiovascular, and immunologic systems.3 The World Health Organization recommends noise level not exceed 35 dB during daytime and 30 dB during nighttime hours.4 Studies consistently indicate that hospitals far exceed the World Health Organization’s recommended levels.5,6

Cardiac monitor alarms can be categorized into 2 types: patient status and technical status. Patient status alarms can be related to potentially life-threatening situations such as apnea or to specific arrhythmias such as ventricular tachycardia.7 Problems generated by monitoring equipment resulting in poor signal quality can lead to technical alarms.8

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Leads fail and arrhythmia suspend were 2 of the most frequent technical alarms experienced by staff using physiologic and cardiac monitors (M. Cvach, unpublished data, 2011). Leads fail alarms occur when 1 or more leads become disconnected. Arrhythmia suspend alarms occur when the monitoring system cannot recognize the patient’s rhythm. Old and dried-out electrodes, motion artifact, or poor skin-electrode contact triggers technical alarms, which result in disruptions in patient monitoring and potentially missed events.9 Alarms such as leads fail have resulted in sentinel events in which patients were found by staff to be unmonitored and in cardiac arrest (Food and Drug Administration, unpublished date). Electrodes and skin preparation were 2 variables thought to be important to reducing the quantity of these alarms.

Electrodes measure electrical activity from the tissue beneath. Surface electrodes measure the skin electrochemical cells and response to the movement of ions. This reaction ends with the production of a current or an electrical impulse.10 Wet gel Ag/AgCl electrodes were in use at The Johns Hopkins Hospital at the time of this project. The hospital’s policy recommended changing electrodes every 72 hours or when the quality of electrocardiogram (ECG) tracing deteriorated.

Concerned about the large number of technical alarms occurring on monitored units and the risk for missed alarms, the Alarm Management Committee at The Johns Hopkins Hospital addressed these issues using an evidence-based quality improvement rapid-cycle change approach. Our aim was to identify and implement best practices for electrode change and to observe the effect of daily electrode change on the number of technical monitor alarms. The practice question asked was, “Does changing electrodes daily decrease the quantity of cardiac monitor technical alarms?”

EVIDENCE APPRAISAL

We conducted a comprehensive search of 4 databases, which included PubMed, EMBASE, CINAHL (Cumulative Index of Nursing and Allied Health Literature), and Google Scholar. The search was limited to English language with a publication date between January 2007 and December 2011. MeSH terms included the following: electrode, lead, electrical impedance, artifact, interference, noise, ECG, EKG, alarms, and physiologic monitor. Of the 502 abstracts reviewed, 52 documents were reviewed in entirety, and 19 sources of evidence were included in an individual evidence summary. We used the Johns Hopkins Nursing evidence appraisal tools to assess evidence strength and quality (Table 1).11

We found good and consistent evidence of a relationship between daily electrode change and a decrease in technical alarms. Although the literature reviewed did not directly refer to technical alarms, evidence regarding a relationship between electrode-skin contact and electrical impedance measurement on signal quality was found.12,13 Studies attributed skin humidity, perspiration, motion, and dried electrodes as the cause of increased skin impedance resulting in artifact and noise.12-15 The best performing electrodes exhibited good adhesive properties producing low impedance.16 Expert opinion and organizational experience suggested that dried electrodes cause electrical noise and motion artifact whereas perspiration causes poor electrode-skin contact leading to poor conduction.7,17,18 Changing electrodes routinely is one way to decrease technical alarms and influence extent of alarm fatigue and errors related to delayed alarm response.19-24 Skin preparation prior to electrode application enhances conductivity by promoting adhesion and skin-electrode contact, resulting in decreased skin impedance and signal noise.7,18,22 We found various methods of skin preparation described in the literature: wash with soap and water, wipe with dried gauze, or “rough up” the skin with sandpaper found on electrode.7,22-24

METHODS

Our hospital’s Office of Human Subject Research confirmed that institutional review
Table 1. Synthesis of Findings*: Does Changing Electrodes Daily Decrease the Quantity of Cardiac Monitor Technical Alarms?

<table>
<thead>
<tr>
<th>Evidence</th>
<th>Total No. Sources/Quality</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level I</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Level II</td>
<td>3 A/B</td>
<td>• Electrodes used beyond first day exhibit poor electrode-skin contact; inaccurate impedance measurement (10); • Factors causing electrodes to become disconnected (12): ○ Patient movement; perspiration; manipulation; defective electrodes • Best performing electrodes (14): ○ Good adhesive properties; low impedance</td>
</tr>
<tr>
<td>Level III</td>
<td>2 B</td>
<td>• Dried electrodes increase electrode impedance and ECG artifact (13) • Skin preparation, where outermost layer of dermis is eroded to decrease motion artifacts, can cause skin irritation and infection (13) • Ag/AgCl gel electrode when dried generates noise and artifact (11) • Electrodes affected by (11): ○ Skin humidity; time of day; seasons; use of skin care products that cause changes in skin impedance • Gel electrodes have low impedance; gel keeps the stratum corneum moist (11) • Dry Ag/AgCl gel electrode performed poorly because of lack of moisture (11)</td>
</tr>
<tr>
<td>Level IV</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Level V</td>
<td>13 A/B</td>
<td>• Survey of biomedical technicians (most frequent electrode problems include) (6): ○ Dried-up electrodes; old or bad electrodes; poor connectivity between patient and electrode • Changing electrodes every 24 h (17): ○ Is one way to decrease the risk of alarm fatigue and delayed alarm response; prevents electrode dryness and poor conductivity • Skin preparation with soap and water provides optimal electrode adhesion for better stimulation and conduction (2, 20, 24) • Dried electrodes and moisture-filled electrodes cause poor stimulation (4, 6, 20) • Causes of electrical noise (artifact) result from the following: loose connections, misplaced electrodes, accumulation of static energy, insufficient or dried gel, poor skin preparation, muscle artifact, mixing brands of electrodes, respiratory artifact by thoracic or abdominal movement, electrical interference, poor electrode contact to skin (4, 15, 25) • Recommend electrodes be changed routinely (19); every 24 h (18, 20, 22-24) ○ Good skin preparation (4, 16, 19); use sandpaper to rough skin up to promote electrode adhesion (21); shaving or clipping hair (25) ○ Ensure electrodes are on flat, nonmuscular areas (4) ○ Check for loose connections (4) ○ Move electrode away from area of greatest movement during respiration (4) ○ Use single brand of electrodes (4)</td>
</tr>
</tbody>
</table>

*Research evidence (levels I, II, and III); nonresearch evidence (levels IV and V). Quality: A (highest) to C (lowest). (#) indicates the reference number for the articles reviewed. JHNEBP Synthesis of Findings form adapted with permission of The Johns Hopkins Nursing/The Johns Hopkins University. Copyright The Johns Hopkins Nursing/The Johns Hopkins University. Reprinted by permission, 2012.
board-deemed approval was not required for this quality improvement initiative because no identifiable patient information was being obtained, and there was minimal risk to the patient. Two adult medical units, whose representatives were members of the Alarm Management Committee, agreed to pilot the daily electrode change intervention. These units were the 15-bed medical progressive care unit (MPCU) and the 25-bed cardiology care unit (CCU), which was a combined step-down/critical care unit.

Our intervention procedure was to perform a daily ECG electrode change during the morning hours between 8 AM and 12 PM. We chose an 8-day timeframe on the basis of previous alarm data extraction reports that demonstrated that 8 to 12 days of alarm data provided a sufficient quantity of data for analysis. The Alarm Committee had baseline alarm data for both units: MPCU baseline data were from January 27 through February 3, 2011; CCU baseline data were from February 23 through March 2, 2011. The data were retrieved by Clinical Engineering through Globe Star Connexall USA Inc., Boulder, CO. Since 8-day convenience samples of alarm data were available, we used the same number of days for observation of the intervention. For MPCU, the pilot intervention period was July 5 through July 12, 2011, and for CCU was August 2 through August 9, 2011. Monitor alarms are prioritized by level of urgency (high, medium, low priority). The monitor indicates level of priority with a distinct audible sound and visual display. We calculated average alarms per bed per day by averaging the midnight census for the 8-day timeframe and dividing the total number of alarms (by priority level) both by the census and by the number 8. This provided the average alarms per bed per day by alarm priority level.

The unit nurse manager explained the intervention procedure to unit clinical technician staff several days prior to the pilot project start date. The technicians, who are unlicensed nursing staff, were instructed to perform a daily electrode change between 8 AM and 12 PM and to follow the hospital’s cardiac monitor policy, which included information on skin preparation and electrode placement:

- clipping or shaving hair from the application site;
- abrading the skin by gently rubbing the area with a gauze pad to remove dead skin cells;
- cleansing the site with soap and water to remove oily residues; and
- drying the skin completely prior to electrode application.

Both units had Solar 8000i (GE Healthcare, Waukesha, WI) monitors. The MPCU used a 5-lead monitor configuration except when acquiring a 12-lead ECG from the monitor. The CCU used a combination of 5- and 10-lead analysis on the basis of criticality of the patient. Typically, 2 leads of ECG and pulse oximetry are displayed on the monitor along with invasive line waveforms; however, multiple-lead analysis occurred regardless of displayed leads. Unit defaults were similar for both areas except the CCU had continuous ST analysis set to audible alarm whereas MPCU had ST analysis set to nonaudible (message) alert.

RESULTS

Table 2 shows the breakdown of technical (system warning) alarms at baseline and during the intervention period for both units. Electrode-related technical alarms included arrhythmia suspend, leads fail, and respiratory rate leads fail. All other alarms were categorized as non-electrode-related technical alarms (eg, noninvasive blood pressure and pulse oximetry probe sensor). All electrode-related technical alarms decreased during the intervention period except leads fail for the MPCU (+13%). Arrhythmia suspend technical alarms were reduced by 60% for MPCU and 74% for CCU. Respiratory rate leads fail alarms decreased by 36% for MPCU and 65% for CCU. Total electrode-related technical alarms (unadjusted for average bed census) decreased by 32% for MPCU and 56% for CCU.
Table 2. Comparison of Technical System Warning Alarms for Medical Progressive Care Unit and Cardiology Care Unit

<table>
<thead>
<tr>
<th>Monitor Alarms Classified as Technical System Warning</th>
<th>Medical Progressive Care Unit</th>
<th>Cardiology Care Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Intervention</td>
</tr>
<tr>
<td>Total electrode-related technical alarms</td>
<td>1336</td>
<td>904</td>
</tr>
<tr>
<td>Arrhythmia suspends</td>
<td>404</td>
<td>160</td>
</tr>
<tr>
<td>Leads fail</td>
<td>310</td>
<td>349</td>
</tr>
<tr>
<td>Respiratory rate leads fail</td>
<td>622</td>
<td>395</td>
</tr>
<tr>
<td>Total non-electrode-related technical alarms&lt;sup&gt;d&lt;/sup&gt;</td>
<td>188</td>
<td>113</td>
</tr>
<tr>
<td>Total all technical alarms&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1524</td>
<td>1017</td>
</tr>
</tbody>
</table>

<sup>a</sup>Percent change was not adjusted for census.

<sup>b</sup>All decreased except where indicated.

<sup>c</sup>All decreased.

<sup>d</sup>Non-electrode-related technical alarms include blood pressure cuff failure, max time and over-pressure; pulse oximetry sensor failure and artifact; other sensor failure; change battery; no telemetry.

<sup>e</sup>Includes all electrode- and non-electrode-related technical alarms.

Table 3 represents the average alarms per bed per day according to alarm category, that is, crisis (high priority), warning (medium priority), advisory (low priority), system warning (technical alarm), and adjusted for average bed census. The overall reduction in average alarms per bed per day was 47% and 46% on the MPCU and CCU, respectively. Technical alarms decreased for MPCU by 34% and for CCU by 45%. Unexpectedly, these data demonstrated a reduction in the number of medium- and low-priority patient alarms,

Table 3. Comparison of Alarms for Medical Progressive Care Unit and Cardiology Care Unit

<table>
<thead>
<tr>
<th>Medical-Progressive Care Unit</th>
<th>Baseline</th>
<th>Intervention</th>
<th>% Decrease</th>
<th>Cardiology Care Unit</th>
<th>Baseline</th>
<th>Intervention</th>
<th>% Decrease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average alarms per bed per day&lt;sup&gt;a&lt;/sup&gt;</td>
<td>183</td>
<td>97</td>
<td>47</td>
<td>195</td>
<td>106</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>High priority</td>
<td>6.4</td>
<td>6</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Medium priority</td>
<td>49</td>
<td>26</td>
<td>47</td>
<td>18</td>
<td>10</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>Low priority</td>
<td>113</td>
<td>54</td>
<td>52</td>
<td>162</td>
<td>87</td>
<td>46</td>
<td></td>
</tr>
<tr>
<td>Technical system warning</td>
<td>15</td>
<td>10</td>
<td>34</td>
<td>11</td>
<td>6</td>
<td>45</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Average alarms per bed per day = total alarms per average daily bed census.
with the greatest decrease noted for advisory alarms (MPCU 52%; CCU 46%) and warning alarms (MPCU 47%; CCU 44%). High-priority (crisis alarms) patient alarms were essentially unchanged.

DISCUSSION

Our results indicate that daily electrode change was associated with a decrease in the number of electrode-related technical alarms, with the exception of the leads fail alarm on MPCU, which increased by 13%. A possible explanation for the increase was that technicians performing electrode replacement did not pause the patient’s alarms prior to the change procedure. We found a substantial reduction in total alarms, with the largest decrease observed in low-priority advisory alarms.

Low-priority advisory alarms are often considered nuisance alarms because of the frequency of occurrence and their association with alarm fatigue. Possible reasons for the reduction in alarms include better skin-electrode adherence, thereby decreasing the likelihood of artifact and impedance, and improved conductivity from wet gel. Our findings are consistent with the evidence that dried electrodes and poor conductivity are associated with an increase in artifact and noise. As a result of this initiative, the Alarm Management Committee recommended a change in policy to require daily electrode change for adult patients. Changing electrodes routinely is one way to decrease the risk of alarm fatigue and errors related to delayed alarm response and (Kaleida Health, unpublished date, 2010).

Performing a daily electrode change may be difficult to implement without defining clear accountability for performing the task. For this intervention, the nurse manager assigned accountability to unlicensed staff who were instructed to perform the task during a specific shift (morning). Defining clear accountability would promote compliance and sustainability. The cost of changing electrodes daily (less than $1 for supplies) is small in comparison with the benefits derived from reduced noise and improved quality of ECG tracings.

Our findings could have been the result of good skin preparation, better electrode-skin interface, consistent practitioners performing the task, or improved skill level of staff assigned to perform the daily electrode change procedure. However, because the effect was repeated on 2 units and data from prior alarm collection periods indicated substantial improvement when compared with these results, the committee was compelled to change practice.

The best available evidence and the results of this quality improvement initiative indicate that changing electrodes daily reduced the quantity of monitor alarms. The hospital’s Cardiac and Physiologic Monitor policy was revised to reflect the need for daily electrode change and good skin preparation. Education was provided on the revised policy, which included the daily electrode change requirement, and this was disseminated to staff electronically as well as posted on the hospital’s nursing Web site. The committee plans to continue to monitor alarms to determine if the effects are sustainable.

REFERENCES

Effect of Daily Electrode Change on Cardiac Monitor Alarms

Abstract presented at: Inter-Noise; December 3-6, 2006; Honolulu, HI.