A NATIONAL ONLINE SURVEY ON THE EFFECTIVENESS OF CLINICAL ALARMS

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Purpose To develop a national online survey to be administered by the American College of Clinical Engineers Healthcare Technology Foundation to hospitals and healthcare workers to determine the problems associated with alarms in hospitals.

Methods An online survey was developed by a 16-member task force representing professionals from clinical engineering, nursing, and technology to evaluate the reasons healthcare workers do not respond to clinical alarms.

Results A total of 1327 persons responded to the survey; most (94%) worked in acute care hospitals. About half of the respondents were registered nurses (51%), and one-third of respondents (31%) worked in a critical care unit. Most respondents (>90%) agreed or strongly agreed with the statements covering the purpose of clinical alarms and the need for prioritized and easily differentiated audible and visual alarms. Likewise, many respondents identified nuisance alarms as problematic; most agreed or strongly agreed that the alarms occur frequently (81%), disrupt patient care (77%), and can reduce trust in alarms and cause caregivers to disable them (78%).

Conclusions Effective clinical alarm management relies on (1) equipment designs that promote appropriate use, (2) clinicians who take an active role in learning how to use equipment safely over its full range of capabilities, and (3) hospitals that recognize the complexities of managing clinical alarms and devote the necessary resources to develop effective management schemes. (American Journal of Critical Care. 2008;17:36-43)
The hospital environment contains countless bells, beeps, and buzzers, most of which are used to monitor the acuity level of patients. Healthcare workers must discern whether these sounds or associated visual alarm displays are clinically important enough to necessitate intervention. Some alarms may indicate a change in a patient's condition (true-positive); others may be considered not clinically important (false-positive); still others may reflect poorly set monitoring parameters.

Although many organizations focus on appropriate deployment of technology at the bedside, it was the Joint Commission on Accreditation of Health Care Organizations (JCAHO) that reviewed 23 reports of death or injury related to mechanical ventilation. Of the 23 events, 19 resulted in death and 4 resulted in coma; 65% were related to alarms. As a result, the JCAHO set 6 national patient safety goals for 2003, one of which was to improve the overall effectiveness of clinical alarms. This goal remained as a national patient safety goal for 2004; after 2004 it was removed from the list and became part of the JCAHO accreditation requirements.

Despite the change in status for the JCAHO patient safety goal for clinical alarms, the frequent alarm-related adverse events reported to the Food and Drug Administration and the Emergency Care Research Institute (ECRI) illustrate that management of clinical alarms still requires attention from healthcare workers and hospital administrators. Healthcare workers report that frequent false alarms are a nuisance for patients and caregivers, and often, if no clinical relevance is apparent, healthcare workers ignore the sound or simply lower the volume to avoid disruptions in patient care.

Alarms on clinical devices are intended to call the attention of caregivers to conditions of patients or devices that deviate from a predetermined "normal" status. Alarms are considered a key tool in improving the safety of patients. The purpose of alarm systems is related to "communicating information that requires a response or awareness by the operator."

In some instances, the normal conditions are preset in the device; in other instances, the correct use of the device requires directly setting the parameter limits. Users often can turn the alarms on or off and set the volume of the audible alarm output.

Alarm information also may be transmitted from the bedside to a remote location down the hall or some distance away. Such transmission may be disabled, either intentionally or inadvertently. When an alarm is triggered, a caregiver is tasked with noting the alarm, identifying its source, and responding appropriately. Effective setting of alarms, noting when alarms go off, and responding to alarms are design issues as well as user issues. From the design perspective, alarms should be easy to set, their status (e.g., on/off, limit values) should be easily determined if not directly visible, and a triggered alarm should be easy to identify and unambiguous. The alarm system also must be designed for all intended environments of patient care.

Because the audibility of patients' clinical alarms directly affects patients' safety, satisfaction, and quality of care, the American College of Clinical Engineers (ACCE) formed the ACCE Healthcare Technology Foundation in 2002 (www.acce-htf.org). One of the organization's first major initiatives was to review, design, and implement a multidisciplinary approach to addressing the issue of clinical alarms. A key goal of this project was to develop an online survey for hospitals and healthcare workers to determine the problems associated with alarms in hospitals.

Methods

A national task force consisting of 16 members from the ACCE Healthcare Technology Foundation...
Clinical alarm management complexity may explain the frequency of alarm-related adverse events.

The survey was divided into 4 main sections. The first section (A-D) requested demographic information from the respondent (e.g., type of facility, job type). The second section (E) provided a number of general statements about clinical alarms and prompted the respondents to rate their level of agreement with the statement, with options for strongly agree, agree, neutral, disagree, and strongly disagree. The third section (F) presented a listing of 9 issues that inhibit effective management of clinical alarms and asked the respondent to rank them on a scale of 1 (most important) to 9 (least important). The final section (G) requested commentary on what is needed to improve recognition of and response to clinical alarms.

The survey was implemented online via SurveyMonkey® from August 15, 2005, until January 15, 2006. It also was made available in a paper version that was used by many healthcare institutions. The completed paper survey forms were reviewed internally at the healthcare institutions, then faxed for loading into the online database for analysis. The paper surveys were beneficial to institutions because they could review feedback and focus on problems with clinical alarms at the hospital level.

Results

The first section (A-D) of the survey yielded information associated with the general demographics of the participants and was completed by 1327 respondents. The majority (94%) of participants worked in acute care hospitals (Table 1). About half of respondents were registered nurses (51%) and one-third of respondents (31%) worked in a critical care unit.

Answers to section E yielded some similarities and some differences between respondents. Most respondents (>90%) agreed or strongly agreed with the statements about the purpose of clinical alarms and the need for prioritized and easily differentiated audible and visual alarms. Other participants identified frequent false alarms as problems (81%), and most agreed or strongly agreed that nuisance alarms disrupt patient care (77%) and that such alarms can cause healthcare workers to "distrust" the alarms and disable the devices (78%; see Figure). Responses were split on whether the proper method of setting alarm parameters is overly complex on existing systems: a total of 49% of respondents disagreed or strongly disagreed with that statement, 28% agreed or strongly agreed, and 23% responded as neutral on the issue. Surprisingly, 72% of respondents agreed or strongly agreed that alarms are adequate to alert staff to changes in a patient's condition.
Two survey statements in section E addressed how alarms are conveyed to staff. About 49% of respondents think that having a dedicated central alarm management staff (ie, monitor watche)s for disseminating alarm information to caregivers is helpful, and 34% were neutral; 54% of respondents see usefulness in integrating alarm information with communications systems (eg, pagers, cell phones), and 30% were neutral.

Section F provided insight into how staff rate the relative contributions of various challenges associated with management of clinical alarms. The items most important for healthcare workers included "frequent false alarms reducing attention to patient care" and "inadequate staffing to respond to the alarms" (Table 2). The most prominent result of the survey was the frustration among staff with the high level of false and nuisance alarms.

Discussion

Our findings are consistent with those of others who have reported that frequent nuisance alarms may affect patients' outcomes related to alarms. Most often the alarms are distracting and interfere with clinicians' ability to perform other critical tasks effectively. Alarms also contribute to desensitization of nurses to the devices, such that alarms for "real" events are less likely to catch the attention of staff. This problem is of particular concern for low-priority alarms (eg, alarms for electrocardiographic leads coming off or alarms for the pulse oximetry sensor coming off), which typically have less ear-catching audible tones than higher priority alarms have. Nurses may not notice and therefore not respond to such alarms, which, in these examples, disable monitoring of the particular parameter, thereby preventing detection of critical conditions in patients. In addition, clinicians sometimes take inappropriate actions to gain relief from frequent nuisance alarms, such as lowering alarm volume, extending alarm limits outside a reasonable range, or disabling alarms altogether.

Some amount of false and nuisance alarms is inevitable. Mitigating the problem posed by them lies in the hands of both device manufacturers and clinicians. Clearly, designs incorporating "smart alarms" (alarms that avoid any loss of signal and alert healthcare workers by ringing) and pulse oximeters that avoid loss-of-signal alarms by reading through (providing readings despite) artifacts are steps in the right technological direction. Equally important is for clinicians to work to minimize nuisance alarms through effective use of equipment. For example, users should select limit settings for heart rate that provide sufficient protection for the patient but do not allow clinically unimportant rate changes to set off nuisance alarms. Proper technique must be used when applying electrocardiographic electrodes to limit alarms indicating that the leads are off. Furthermore, alarms must be addressed promptly, because conditions that are left unresolved typically result in ongoing alarms.

As devices become more sophisticated, complexity increases. Healthcare workers are charged with effectively managing numerous bedside devices, and each device has an alarm. Often nurses are responsible for setting alarms properly and responding to each alarm promptly— for each device and for each patient—while still managing all other tasks not related to alarms. Furthermore, nursing staff must deal with a high frequency of false alarms (eg, a tachycardia alarm triggered by the effect of a patient's movement on the electrocardiogram) and nuisance alarms, alarms that do not indicate a clinically important condition that requires attention. (An example of a nuisance alarm would be a "high pressure" ventilator alarm caused by a patient's cough.)

Hospitals must have appropriate policies to ensure proper training of all healthcare workers who use these devices and alarm systems. Geography and staffing of critical care units must be arranged in such a way that all alarms can always be heard by staff. Failure to meet any of these challenges can allow alarms to be missed by clinicians, perhaps resulting in a critical condition in a patient going unnoticed. The complexity of managing clinical alarms explains why, despite the abundance of device alarms, alarm-related adverse events still occur with worrisome frequency.

Table 2

<table>
<thead>
<tr>
<th>Issue</th>
<th>Rankinga</th>
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<tbody>
<tr>
<td>Frequent false alarms reduced attention to patient</td>
<td>1</td>
</tr>
<tr>
<td>Difficulty in setting alarms properly</td>
<td>3</td>
</tr>
<tr>
<td>Difficulty in hearing alarms when they occur</td>
<td>2</td>
</tr>
<tr>
<td>Difficulty in identifying the source of an alarm</td>
<td>2</td>
</tr>
<tr>
<td>Inadequate staff to respond to alarms as they occur</td>
<td>1</td>
</tr>
<tr>
<td>Overreliance on alarms to call attention to patients' problems</td>
<td>3</td>
</tr>
</tbody>
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a Rank order: 1 = most important, 2 = somewhat important, 3 = not important.

When nurses become desensitized to alarms, "real" events fail to catch their attention.

Clinicians can minimize alarms through effective use of equipment, but proper training must be provided.
Many of the responses to the survey indicated that (1) alarm settings are not overly complex, and that (2) lack of training on alarms, compared with other alarm management issues, is not an important concern. Yet ECRI has reported from its experience that problems often stem from alarms being improperly configured or inadvertently defeated by staff. Both the design of the device’s alarm system and the healthcare worker’s level of proficiency contribute to this problem. Therefore, effective and ongoing training is still of vital importance. Although many alarm systems seem straightforward on the surface, the intricacies are often not well understood by staff. A common example is the many ways alarms on a physiological monitoring system can be defeated. One action may silence an existing alarm; another may disable all alarms for a time; still another may indefinitely disable alarms. Not understanding these differences can lead to inappropriate actions for the given circumstances, a situation that can and does lead to adverse events.

Our survey showed that most respondents were nurses, and responses emphasized the burden of nuisance alarms whereas they de-emphasized the need for additional training. This outlook illustrates the current state of management of clinical alarms in hospitals: Many healthcare workers view alarms as one item on a long list of tasks to be managed rather than as an enabling tool that improves the staff’s ability to stay informed of their patients’ conditions. Results from this survey indicate that alarm management may be solely a technology problem. Clearly, frequent nuisance alarms have played a role in breeding this mind-set, and technology improvements are a necessary component in addressing this problem. Understandably, effective alarm management relies on how the technology and the human elements intersect. Compounding the “alarm burden” felt by healthcare workers, alarm management may be more consistent with the hospital administrator’s overall approaches to patient care or safety. Consider the following:  
- Are alarms sufficiently audible to alert healthcare workers wherever the workers may be, especially in an environment with many competing alarms?  
- Do current staff levels allow enough time to manage the large number of alarms?

- Have devices been configured to minimize nuisance alarms?  
- Have healthcare workers received adequate training?  
- Are adequate methods of communication between healthcare workers available to communicate alarm information and facilitate response?

Effective clinical management of alarms relies on (1) equipment designs that promote appropriate use (eg, easy to set, obvious visual indicators when alarms have been disabled), (2) healthcare workers who take an active role in learning how to use equipment safely over its full range of capabilities, and (3) hospitals that recognize the complexities of managing clinical alarms and devote the necessary resources to develop effective management schemes. As stated by a survey respondent, a “combination of technology and nursing process adjustments must be implemented in order to effectively address this issue. Smart alarms, improved communication systems, directing alarms to the caregivers, training, accountability regarding alarm response policies, etc, all should be helpful in reducing the risk.”

**Recommendations for Clinical Practice**

The general public reports that nurses are the most “trusted” patient care providers” because nurses provide 24-hour care and are always monitoring patients’ conditions. Nursing personnel and other healthcare workers remain the first line of defense for safety within the critical care environment. Thus, it is important for healthcare workers to use the alarms effectively for safe clinical practice. On the basis of this survey study, the following clinical recommendations are important:  
- Daily rounds to monitor safety of clinical alarms  
- Completion of a checklist to provide information on clinical alarms, documented by computer charting completed at the beginning and end of each shift  
- In-service training for use of new equipment and simulation training in its use  
- Monthly discussion of adverse events associated with clinical alarms  
- Implementation of annual review of data associated with nuisance vs nonnuisance clinical alarms

We also recommend a system-wide education plan associated with the proper use of clinical alarms that would ensure competency and knowledge about appropriate responses by all healthcare workers. A multidisciplinary approach to clinical alarms for the protection of patients would include clinical
protocols that would improve responsiveness to alarms and guide in the development of clinical policies consistent with the routine testing of alarms. Implementation of a system-wide education plan would assist in the evaluation of "risk assessments" associated with staff knowledge, responsiveness, and adverse events, and would provide a safer environment for patients.11

Study Limitations

Although this study was a national survey, it had several limitations that may have influenced our results. First, the survey was based on the participants' general opinion; information was solicited via our survey tool. Several research methodologists have shown that survey data may not accurately reflect or report data about a subject area. Others, however, have shown that when comparison interview data are solicited from the same subjects, survey data may "mirror" the responses. Other limitations of the study included a convenience sample; the respondents were nurses or professionals who were already knowledgeable about audible alarms and worked in critical care units as indicated by our links with nursing professionals. Clinical or biomedical engineers and clinical managers who answered the survey may have been all too familiar with the use of alarms on healthcare equipment.

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FINANCIAL DISCLOSURES

None reported.

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