Aims and objectives. To describe the cues and factors that nurses use in their
decision-making when responding to clinical alarms.

Background. Alarms are designed to be very sensitive, and as a result, they are
not very specific. Lack of adherence to the practice standards for electrocardio-
graphic monitoring in hospital settings has been observed, resulting in overuse of
the electrocardiographic monitoring. Monitoring without consideration of clinical
indicators uses scarce healthcare resources and may even produce untoward cir-
cumstances because of alarm fatigue. With so many false alarms, alarm fatigue
represents a symptom of a larger problem. It cannot be fixed until all of the fac-
tors that contribute to its existence have been examined.

Design. This was a qualitative descriptive study.

Method. This study was conducted at an academic medical centre located in the
Northeast United States. Eight participants were enrolled using purposive sampling.
Nurses were observed for two three-hour periods. Following each observation, the
nurse was interviewed using the critical decision method to describe the cognitive pro-
cesses related to the alarm activities. Qualitative data from the conducted interviews
were analysed via an a priori framework founded in the critical decision method.

Results. This study reveals information, experience, guidance and decision-making
as the four prominent categories contributing to nurses’ decision-making in rela-
tion to alarm management. Managing technology was a category not identified a priori that emerged in the data analysis.

Conclusion. Nurses revealed a breadth of information needed to adequately iden-
tify and interpret monitor alarms, and how they used that information to put the
alarms into the particular context of an individual patient’s situations.

Relevance to clinical practice. Understanding the cues and factors nurses use
when responding to cardiac alarms will guide the development of learning experi-
ences and inform policies to guide practice.

Key words: cognitive task analysis, critical decision method, equipment alarm sys-
tems, monitoring, nurse decision-making, physiological

What does this paper contribute to the wider global clinical community?

- The universal use of continuous ECG monitoring for patients in
  acute care settings has implications for the workflow of regis-
  tered nurses.
- The findings from this study validate gaps in cardiac monitoring
  and alarm management, as well as identifying the unique situated
decision-making of nurses.
- This study provides a new lens through which to view the prob-
  lem of monitor alarms and the nursing work associated with
  alarms.

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Introduction

The numbers and types of alarms in the clinical environment are staggering. There are alarms that detect changes in patient condition, alarms that monitor the proper function of equipment and various other types of alarms. The frequency of clinical alarms in acute care hospitals continues to present challenges to patient safety and has been identified as the number one health technology hazard for 2013 (ECRI Institute 2012). Attention to clinical alarms has increased following the death of a patient in 2010, determined to be the result of an alarm that had been inadvertently turned off (Kowalczyk 2010). Patient deaths and injuries related to clinical alarms represent the very real adverse events that result from inadequate alarm management. Adverse events also include harmful health effects for patients and clinicians related to constant stress-producing noise. Additionally, the risks and costs associated with clinical alarms and their related equipment remain unquantified. In June of 2013, the Joint Commission approved a new National Patient Safety Goal for 2014 related clinical alarm safety for hospitals (The Joint Commission 2013).

Alarms are intended to monitor and alert clinicians, primarily nurses, of a change in patient condition. This type of monitoring of patient condition is one part of the nurse’s assessment process that supports nursing surveillance (Henneman et al. 2012). Responding to clinical alarms is an observable activity that is driven by complex, unobservable cognitive processes that make up surveillance of patient condition. With so many alarms in the clinical environment, the scope of this study was limited to continuous electrocardiographic monitors, a common type of monitor used in hospitals to detect changes in patient condition.

Background


Observation on a clinical unit is a cacophony of noises. In addition to alarms that are meant to alert the nurse of a change in condition (i.e. heart and vital sign monitoring) or function of equipment (i.e. intravenous pumps, ventilators), there are pagers, phones, call bells and chair alarms. Even with so many alarms in the environment, it is clear that as new technology is developed, more alarms will follow (Pope 2010). For example, capnography is currently being integrated into medical surgical units for the monitoring of patients on patient-controlled analgesia (Stoelting & Overdyk 2011).

Alarms are designed to be very sensitive so as a result, they are not very specific. Investigators in an observational study of emergency room patients presenting with chest pain receiving continuous electrocardiographic (ECG) monitoring over 371 hours reported an alarm rate of 4.7 alarms per monitor hour. Of a total of 1762 alarms, 11 were adverse events, resulting in a false alarm rate of 99.4% (95% CI, 98.9-99.7). None of the adverse events were hemodynamically significant (Atzema et al. 2006). Only three of the adverse events resulted in a change of patient management and very few of the alarms provided clinically relevant information. Not only is the monitoring equipment producing many false alarms, it appears that continuous ECG monitoring is overused.

The American Heart Association (AHA) has published practice standards for ECG monitoring in hospital setting (Drew & Funk 2006). Lack of adherence to the AHA guidelines has been observed, resulting in significant overuse of the ECG monitoring (Kanwar et al. 2008, Leighton et al. 2013). This overuse of a technology with limited clinical relevance only compounds the issue of the number of false alarms that leads to alarm fatigue. Monitoring without consideration of clinical indicators uses scarce healthcare resources and may even produce untoward circumstances (Larson & Brady 2008).

Alarm fatigue is often cited as a cause of alarm adverse events. Most writers, however, neglect to consider what alarm fatigue really means, and the public interprets this as simply being tired of the alarms. Alarm fatigue is a complex cognitive process that is not voluntarily controllable. In fact, alarm fatigue is a human adaptive mechanism triggered to manage cognitive burden and attention resources. Researchers have described this phenomenon as the ‘cry wolf effect’ wherein the human behavioural response to alarms is adjusted according to the perceived false alarm rate (Bliss & Dunn 2000). Bliss and Dunn’s (2000) research demonstrated that when there is a low rate of false alarms, human responses to the alarm are more appropriate. With high rates of false alarms, the natural human response is to
respond less frequently. Continuous ECG monitoring alarms have false alarms rates as high as 99.4% (Atzema et al. 2006). Extrapolating from Bliss and Dunn’s (2000) work, for a system producing false alarms higher than 90%, such as continuous ECG monitoring, a response should be expected less than 10% of the time. With so many false alarms, alarm fatigue is the symptom of a larger problem and not the problem itself. It cannot be fixed until all of the factors that contribute to its existence are examined.

It is clear that alarms are ubiquitous in today’s clinical environment, and although there is a need to design technology that makes alarms more clinically relevant and room for improvement in adhering to the American Heart Association guidelines (Drew & Funk 2006), there is an immediate need to improve the education of nurses in the use of ECG monitoring and alarm management. Preliminary results from the PULSE trial have demonstrated that nurses have insufficient knowledge to effectively use current monitoring systems (Funk et al. 2009b). In addition, it has been documented that nurses do fully not understand all of the complexities of the monitoring equipment (Korniewicz et al. 2008). Success in decreasing nuisance alarms has been achieved with quality improvements programmes that rely heavily on re-education of nurses on topics such as setting appropriate alarm limits, individualising alarm limits, troubleshooting common monitor problems, modifying alarm default limits (Graham & Cvach 2010).

The data reported in this manuscript are part of a project with the overall aim to create an evidence-based education to teach nurses to correctly identify and interrupt monitor alarms. This prospective, descriptive mixed method project includes describing the frequency and types of alarms encountered (Gazarian 2013a) and the cues and factors that nurses employ in identifying and interrupting monitor alarms in clinical practice. Following data collection, a simulation scenario will be created that incorporates evidence-based common alarm situations in a real-time simulated learning situation. The purpose of this article was to describe the cues and factors that nurses employ in identifying and interrupting monitor alarms in clinical practice.

Methods
Design
The data that are reported here are part of a prospective, descriptive project designed to elicit information on how nurses identify and interrupt monitor alarms. This prospective, descriptive mixed method project includes describing the frequency and types of alarms encountered (Gazarian 2013a) and the cues and factors that nurses employ in identifying and interrupting monitor alarms in clinical practice. Following data collection, a simulation scenario will be created that incorporates evidence-based common alarm situations in a real-time simulated learning situation. The purpose of this article was to describe the cues and factors that nurses employ in identifying and interrupting monitor alarms in clinical practice.

Setting and participants
This study was conducted in an academic medical centre located in the Northeastern USA. The sample was drawn from the population of registered nurses who regularly cared for patients receiving continuous ECG monitoring. Starting with a general medical intermediate care unit, the principal investigator (PI) approached the unit leadership to describe the project, obtain permission to observe nurses on their unit and solicit names of registered nurses who would be potential participants. Nurses were excluded if they were currently being precepted or oriented to a new position. Potential participants were approached by the PI and asked to participate. Further participants were recruited using purposive, snowball sampling technique. Eight participants were enrolled (Table 1).

Ethical considerations
The applicable human research ethics committees approved the study and deemed the study exempt. Participants who agreed to participate were informed of the study purpose by the PI and signed written consent.

Data collection
Once participants had been identified, and consented to participate, permission was obtained from the unit’s nurse director to observe each nurse during a shift on the unit. The nurses’ upcoming work shifts were reviewed and arrangements made to complete two three-hour observations within one week. At the end of each observation period, the recorded events from the central monitor station were retrieved. Following the second observation period,

Table 1 Study participant demographics and experience

<table>
<thead>
<tr>
<th>Highest degree in nursing</th>
<th>7 BSN</th>
<th>1 AD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>8 female</td>
<td></td>
</tr>
<tr>
<td>Staff nurse</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Preceptor</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Charge</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>23.00–45.00</td>
<td>29.75</td>
</tr>
<tr>
<td>Years experience as an RN</td>
<td>1.00–7.00</td>
<td>3.65</td>
</tr>
<tr>
<td>Hours worked per week</td>
<td>32.00–40.00</td>
<td>37.00</td>
</tr>
</tbody>
</table>
the nurse was interviewed using the critical decision method to describe the cognitive processes related to the alarm activities recorded by observation and the central monitor. All interview data were recorded and transcribed verbatim.

The critical decision method is a type of cognitive task analysis that attempts to make the knowledge, judgements and strategies underlying observable behaviour explicit (Gazarian 2013b). The critical decision method employs a structured retrospective interview centred on a specific case that is guided by questioning and several retellings of the incident with distinct steps as summarised below (Crandall et al. 2006).

Before conducting the interviews, an interview guide was developed and adapted based on the critical decision method. Hospital policies and standards of practice were reviewed, and the research team familiarised themselves with the monitoring equipment in use.

The alarm incidents probed were the alarm events observed and/or recorded from the central monitor station that occurred during the observation period. The interviews began with the participant recalling the alarm incident from beginning to end. Next, the PI repeated the incident back to the participant in order to arrive at a common understanding of the situation. The participant was able to view the observation logs and the recorded alarm events. Together, the participant and PI reviewed the logs and recorded events to identify the points where they received information, took action or made decisions. These points were then probed with more specific questions about the alarm incident. Finally, the PI asked the participants about any previous training or education they had related to continuous ECG monitoring.

Table 2 Trustworthiness of the data

<table>
<thead>
<tr>
<th>Prolonged engagement: spending adequate time to learn about the context and culture of the setting and to build trust among the participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Member checks: sharing the data, analytic categories, interpretations and conclusions with those from whom the data were collected</td>
</tr>
<tr>
<td>Triangulation: using one source, data, method or theory can be compared against another</td>
</tr>
<tr>
<td>Peer debriefing: exploring the process of inquiry with a ‘disinterested peer’ in order to explore biases, test hypothesis and examine feelings that may impair judgement on the part of the investigator</td>
</tr>
<tr>
<td>Transferability: determining to what extent the results of the study can be transferred to other contexts. Thick description refers to providing relevant and detailed descriptive data</td>
</tr>
<tr>
<td>Dependability: auditing the inquiry process. Confirmability: examining the product to demonstrate that the process and product are consistent and coherent. Accomplished through an audit trail</td>
</tr>
</tbody>
</table>

Data analysis

Qualitative data from the conducted interviews were analysed via an *a priori* framework founded in the critical decision method. According to the critical decision method, rationale behind clinical action is delineated as follows: (1) perceptual cues, (2) information, (3) experience, (4) decision-making, (5) guidance and (6) goals. The perceptual cues category included data relating to sensory perceptual data. The information category included data relating to what information the nurse used, how, when, from whom that information was obtained and what was done with the information. The category of experience included data about previous training, mental models or previous experiences. The decision-making category included data about options, judgement of options and time pressure. The guidance category included any data pertaining to seeking guidance from others. Lastly, the category of goals related to data about the priority objective or goal of the situation (Crandall et al. 2006). All transcripts were reviewed according to these six categories.

Trustworthiness

To assure that study findings are congruent with the data collected, Lincoln and Guba’s (1985) methods of credibility, transferability, dependability and confirmability were foundational in demonstrating the trustworthiness of the data. Specifically, the research team (the PI and four graduate nursing students) employed prolonged engagement, member checks, triangulation, peer debriefing and a careful audit trail of data as described in Table 2. A four-step pro-
cess was implemented to conduct the qualitative data analysis as described in Table 3.

Results

Participants identified cues and factors contributing to a response in caring for patients on ECG monitoring during their shift. Interview data revealed 282 cues and factors used when responding to monitor alarms. Table 4 summarises the number of responses per category. Findings were initially organised into an a priori framework based on the critical decision method and categorised as follows: (1) information, (2) experience, (3) guidance, (4) decision-making, (5) perceptual cues and (6) goals. Further content analysis revealed an additional category specifically related to managing the technology. Participants shared their experiences of caring for patients on ECG monitoring and discussed important cues and factors that influenced their responses to cardiac monitor alarms. Participants’ experiences are described below. Examples of quotes from individual interviews that exemplify major categories are included in the text.

Information

Nurses described using information from shift report and past medical history in their assessments of ECG patients and response to cardiac monitors of these patients. Examples of key words used in the information category include: ‘report’, ‘cardiac history’, ‘past medical history’, ‘tachycardia’, ‘a-fib’ [atrial fibrillation], ‘pacer’ [pacemaker] and ‘labs’ [laboratory results]. One nurse described:

I think they told me in report when she had been getting a little bit brady [cardiac] as well. She had some low blood pressure issues. So we were holding a lot of her blood pressure meds and heart meds. (Participant # 9)

Experience

Experience was exemplified as the nurse explained:

She was getting albuterol nebs so I knew, obviously she has the chance for her heart rate to go tachy [cardiac] and when she walks around she gets more short of breath so I knew that her heart rate was going to go up ... I know from experience with my other asthma exacerbation, COPD [chronic obstructive pulmonary disease] patients, that when they get up and walk around, their heart rate usually goes up. (Participant # 2)

A second nurse explained her past experiences with EP (electrophysiology) patients and how those impact her monitoring stating:

The EP patients ... There are some of these ablations that go for six, eight hours and they’re nauseous, they’re vagaling, they’re feeling crummy when they come up. You’re giving them Zofran, you’re giving them Pepcid. They’re not necessarily, you know bradycardiac or anything awful. Then there are some that end up having pericarditis. Some have effusions, which are rare, but some of them do great, and some of them just feel ... you never really know what you’re going to get ... Once or twice we had a patient that is like bradying down like wow that’s turned into second degree heart block ... and then you have to call for EP and all that. (Participant # 7)

Another example of a nurse using prior experience to monitor patients occurred when she explained, ‘when you get to know your patients you can anticipate what the alarms are going to be’. (Participant # 1)
Guidance

All participants stressed the importance of thorough communication about patients during report at change of shift. Obtaining accurate report on patients from other staff helped nurses to guide their actions in caring for the patient. One nurse described her frustration with reporting at change of shift:

It is difficult because a lot of people give report very fast, they don’t go into the history sometimes, and I think that is very important, even if the patient has been on the floor multiple times. (Participant # 3)

Key phrases mentioned by the participants were: ‘because it was in the orders’, ‘because the nurse told me during change of shift’ and ‘after conferring with the doctor’. These phrases directly aided the participant in interpreting a monitor alarm. Additionally, educational resources serve as a guide for nurses caring for patients receiving continuous ECG monitoring. Participant # 8, mentioned that having an arrhythmia recognition poster on the unit has been helpful: ‘When a rhythm is in question, nurses are able to use the poster for comparison’. Verifying a patient’s rhythm helped to determine whether an intervention was necessary.

Several participants raised concerns about lack of clarity and use of the monitoring protocol stating: ‘everyone’s on it’, and ‘the telemetry (ECG monitor) comes off at the same time the IV (intravenous) comes out, at discharge’.

Decision-making

A new graduate nurse described her thought process when attending to unstable patients, stating:

I just try to go with my gut … instead of just checking the telemetry [ECG monitor] or writing it down every hour, I’ll be checking it every half hour. If they have … a cardiac event, then I’ll be checking their stuff every five to fifteen minutes … until they’re stable. (Participant # 4)

Decision-making was employed in the selection of patients warranting continuous ECG monitoring. One nurse explained her decision behind discussing patient removal from a cardiac monitor with the medical team stating: ‘since she didn’t have any cardiac history, we didn’t feel like it was necessary for her to be on [ECG monitoring]’. Another nurse reported that her patient in:

sinus tach [acardia] … was appropriately warranting telemetry (ECG monitoring) … to make sure that she didn’t start creeping up and have any kind of additional tachycardia issues. (Participant # 8)

Decision-making was also used as a mechanism to avert excess alarm noises. A participant clarified her decision to assess a patient when, ‘a V [chest] lead had come off’, further explaining that she chose to, ‘switch out the stickers … and change them all around’ as a pro-active measure to cut back on potential nuisance alarms. Another nurse described her choice to increase a patient’s alarm limit setting from 120 beats per minute to this individual patient’s recurring high heart rate of 125 beats per minute in order to eliminate, ‘silencing the alarms’ and establish more significance, appropriateness and urgency to the sounding of his alarm.

Perceptual cues

Key phrases used throughout the interviews included: ‘look’, ‘keep watching it’, ‘tune in’ and ‘hear the sound’. In one interview, a nurse said: ‘… otherwise you don’t have any picture unless you actually go in there and really assess them’. Another nurse described getting:

… used to picking out which sounds are more alarming and kind of like knowing which patient’s on the floor. If you see … a high heart rate that’s sustained, you’ll go check if that person is walking or moving around or something else. (Participant # 1)

In contrast, a nurse described processing the perceptual information without an observable response:

If someone’s in A-fib and their heart rate goes up to like 133 quickly for like three-seconds, it’ll beep. If they drop back down below that parameter, it’ll stop. (Participant # 2)

Visual data provided nurses with a piece of the picture of their patient. One nurse on the thoracic unit, where oxygen saturation is closely watched, described when the oxygen saturation probe comes off, ‘you lose part of your vision’. Perceptual cues signalled the need to seek more cues. For example, one participant described hearing the alarm, then seeing the increased heart rate and then noting the patient felt warm, prompting her to take the patient’s temperature. Participants described filtering the perceptual cues. One technique that several nurses described was to identify their assigned patients by selecting one unique colour for displaying their patients’ rhythm. Lastly, nurses used perceptual cues from the central monitor display to provide information about the unit, or a quick look to see that everyone was okay. One participant admitted that ECG monitoring data were ‘reassuring’.
Goals

Key phrases from participants included: ‘that was my priority’ and ‘it was standard for her [to be on a cardiac monitor because] they were making sure she didn’t have an MI [myocardial infarction]’. One participant related her experience to a patient suffering congestive heart failure with the primary goal to maintain regular heart rate, stating: ‘he had come into the ED [emergency department] and he was a little bit brady [cardiac] … so we were monitoring him for that’. Another nurse spoke of a patient with a history of atrial fibrillation who, ‘was in a-fib all the time’. She elaborated that: ‘he was mostly rate controlled but he had some episodes where he was not rate controlled so he was on the cardiac monitor for that’.

Technology

Nurses stated that they do not fully understand all the functions of the cardiac monitor systems, and when technology failure occurs, it is complex to troubleshoot the source of the issue. One nurse listed the features and complexities of monitor technology including but not limited to:

event history … modifying alarms…the different ways they sound … syncing up the inside [bedside] monitor and the outside [central station] monitor … and how to change it if you need to.

Another concern was that terms used to label alarms were not consistent or clear:

I don’t think when people see arrhythmia suspend that they actually know like whatever it says it’s not really accurate. Arrhythmia suspend basically means there’s too much artifact in whatever signals it’s getting. The patient could be in VT [ventricular tachycardia], asystole or normal sinus and it can’t tell. (Participant # 7)

Participant # 2 stated, ‘I think there is still a lot of things with that monitor that I don’t even know how to do’.

Discussion

The goal of monitor alarms is to alert clinicians about changes in the patient’s physiological condition. Inadequate alarm management can generate constant stress-producing noise, leading to alarm fatigue and consequently adverse clinical outcomes (Larson & Brady 2008). Understanding more about how nurses interact with monitor alarms is a first step in improving alarm management. This study validates what has previously been described related to cardiac monitoring and alarm management, but extends that knowledge by identifying the unique situated decision-making of nurses related to alarm management.

Information prevailed as the principal category for participant experiences, prompting one-third (33.3%) of the nurses’ responses to monitor alarms. Experience is another predominant category in this study, contributing to one-fifth (21.9%) of the nurses’ reactions to clinical alarms. Guidance was also a major category, responsible for 18% of monitor alarm responses. The decision-making category ranked a close fourth, accounting for approximately 16% of the cues and factors provoking nurses’ reactions to clinical alarms. Minor categories in this study include perceptual cues, eliciting fewer than 10% of nurses’ responses, and goals and technology, each prompting fewer than 3% of responses to clinical alarms.

Nurses revealed a breadth of information needed to adequately identify and interpret monitor alarms, and how they used that information to put the alarms into the particular context of an individual patient’s situation. The need for context was prominent in the experience category. Nurses relied on their previous experiences with a population of patients (such as electrophysiology patients) as well as knowledge of the individual patient from previous experiences caring for that individual to anticipate possible alarm conditions. Interview data revealed how nurses make decisions about how and when to best use continuous ECG monitoring in individual situations. Lastly, nurses discussed the complexity of the technology.

Limitations

The major limitation of this study was the fact that nurses were aware of being observed. In overt observation, individual behaviour and nursing actions may be modified during the observation period. Additionally, retrospective retellings of events are never completely accurate; however, use of the structured probes of the critical decision method can improve the retelling of events. Verifying the events with other sources of information strengthens retrospective accounts. In this study, we collected observations of the nurses, as well as computer-recorded alarm histories.

Another limitation is the mean age of participants; mean participant age of 29.75 years is younger than mean age of 45.36 years of nursing staff across the entire hospital. This was a small sample, with eight participants interviewed from one medical institution. However, as is true of qualitative research, knowledge of the study setting and participants allows the reader to make a judgement about the
transferability of the findings from this study to another practice environment.

Relevance to clinical practice

This study affirms findings of previous researchers who have described the prevalence of alarms and the number of false alarms in the clinical setting. Additionally, it is a beginning effort to reveal the cognitive work that nurses engage in while managing alarms. Most importantly, no clinical monitoring system will ever elicit a patient’s subjective data and the sensory perceptual observation data that only clinicians can access and observe. The universal use of continuous ECG monitoring for patients in acute care settings has weighty implications for the workflow of registered nurses. As our society becomes more connected to technology, the number of alarms and alerts in the nurses’ work environment will only increase. It is imperative that we learn how to best to integrate technology into our workflow. The need to understand how this technology affects nursing practice is urgent. Its misuse may lead to adverse events, and its overuse produces an increase in nurses’ work with little documented effect on patient outcome.

References


Conclusion

The findings from this study validate gaps in cardiac monitoring and alarm management, as well as identifying the unique situated decision-making of nurses. Understanding the cues and factors nurses use when responding to cardiac alarms will guide the development of simulated learning experiences and inform policies to guide practice. Focused training will be designed to educate nurses on effectively assessing patients’ monitoring requirements and successfully managing monitor alarms to provide safe patient care.

Disclosure

The authors have confirmed that all authors meet the ICMJE criteria for authorship credit (www.icmje.org/ethical_1author.html), as follows: (1) substantial contributions to conception and design of, or acquisition of data or analysis and interpretation of data; (2) drafting the article or revising it critically for important intellectual content; and (3) final approval of the version to be published.
patients can safely be removed from cardiac monitoring in the emergency department. Annals of Emergency Medicine 50, 136–143.


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