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Alarm Fatigue: A Risk Assessment

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ALARM FATIGUE: A RISK ASSESSMENT

by

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Abstract

Alarm fatigue is the phenomenon which occurs when nurses become overwhelmed by the high number of alarms in the clinical environment. This is a significant patient safety issue as delayed or inappropriate responses can and have resulted in patient harm. The purpose of the observational study was to conduct a risk assessment of alarm fatigue at an acute care teaching hospital in Providence, RI. Observations of telemetry alarms and response were conducted, utilizing a standardized tool on two medical surgical units over a six week time period. Participants were 36 nurses working on the two units at time of observations. Alarms were quantified to determine the percentage of false, technical, valid, and nuisance alarms. Alarm frequency was calculated and average response time to critical and leads off alarms were determined. Nurses were found to be at risk for and experiencing alarm fatigue based on high alarm frequency, increased number of false and nuisance alarms, and a delayed response to leads off conditions. The findings in this study are consistent with what is occurring in healthcare organizations nationally, as evidenced by a recent Joint Commission Sentinel Event Alert about medical device alarm safety that cited alarm fatigue as a major contributing factor. Recommendations and implications are presented and discussed.

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Problem Statement

The Joint Commission (TJC) defines a clinical alarm as "any alarm that is intended to protect the individual receiving care or alert the staff that the individual is at an increased risk and needs immediate assistance" (Phillips & Barnsteiner, 2005, p. 317). The acute care clinical environment has at least 40 alarm sources and an alarm may occur as often as every 30 seconds (Phillips, 2006). These alarms creates a cacophony of sound that can be overwhelming for nurses and may result in alarm desensitization as well as inappropriate alarm management practices, both of which can significantly impact patient safety (Bell, 2010). In 2002, TJC recognized the potential hazard of excessive alarms and developed two patient safety goals to improve the effectiveness of clinical alarms. In 2004, alarm safety became a Joint Commission Environment of Care standard (Healthcare Technology Foundation [HTF], 2006). Despite these actions, clinical alarm management remains an issue in healthcare and continues to impact patient safety. The ECRI Institute, a nonprofit and federally designated patient safety organization, identified alarm hazards as the number one health technology hazard in 2012, recognizing that alarms have attributed to the occurrence of many adverse patient events (ECRI Institute, 2011). In 2013, alarm safety has once again become a TJC priority. Alarm system management is the focus of a proposed 2013 National Patient Safety goal (Association for the Advancement of Medical Instrumentation [AAMI], 2011).

Alarm fatigue is the phenomenon which occurs when nurses become overwhelmed by the high number of alarms in the clinical environment (ECRI Institute,

2011). Physiological monitoring, with bedside or telemetry cardiac monitoring systems, is the source of most these alarms and is the most likely to result in harm if not swiftly addressed (Harris, Manavizadeh, McPherson, & Smith, 2011). In 2011, Liz Kowalczyk wrote a series of articles for the *Boston Globe* introducing the phenomenon of alarm fatigue to mainstream America. These articles highlighted several national cases which resulted in poor patient outcomes, including death, due to cardiac monitoring alarms which were ignored or not responded to in a timely manner. Since that time, several other stories involving patient deaths during hospitalization have cited alarm fatigue as the cause. A 2011 survey conducted by HTF found that almost one in five institutions have experienced adverse patient events related to clinical alarm problems (HTF, 2011). Alarm fatigue is a growing epidemic which appears to be impacting health care facilities across the nation. As the evidence regarding this phenomenon continues to expand, much of the work has focused on critical care and progressive care units, with little attention paid to medical surgical units, where the stakes may be even higher. The increased patient to nurse ratio as well as the architectural layout of many medical surgical units makes this population at an increased risk. The purpose of this observational study was to determine if nurses working on two medical surgical units at an acute care teaching hospital in Providence, RI were at risk for and were experiencing alarm fatigue.

Review of the Literature

An extensive review of literature was conducted utilizing PubMed and CINAHL. Keywords used for the search included alarm fatigue, false alarms, clinical alarms, telemetry, and nurses' role and alarms. No limits were set for the searches conducted. Articles reviewed were published primarily in the past 10 years, with the exception of two articles which were published in 1999 and 2001. One landmark study related to alarm reliability and response, published in 1995, was also included in the review. The literature reviewed included performance or quality improvement initiatives, white papers published by alarm safety organizations, surveys, narrative reviews of current literature, and guidance articles which provided suggestions for alarm evaluation and management. Three observational studies and two retrospective alarm analysis studies were also examined. A thorough search revealed no meta-analyses, randomized control trials, or experimental design studies related to alarm fatigue.

TJC recognized the patient safety risk associated with clinical alarms several years before the phenomenon of alarm fatigue was identified. In 2002, TJC published a sentinel event alert regarding the injury or death of patients who were receiving mechanical ventilation. Sixty-five percent of these incidents were attributed to alarm mismanagement or malfunction (Sendelbach, 2012). In 2003, TJC developed a two part national patient safety goal related to clinical alarms. The first part of the goal was to improve alarm effectiveness by implementing regular maintenance and testing of systems. The second part was to ensure that alarms were activated with appropriate settings and were audible enough to be heard against other competing sounds on the unit.

This goal existed for two years. In 2005, clinical alarm safety became a standard in the TJC Environment of Care Standards (Phillips, 2006). Although alarm management practices still apply under TJC Environment of Care and Human Resources accreditation standards, adverse events related to alarms continue to occur (ECRI Institute, 2008). As a result, the TJC has proposed that in 2013 a new National Patient Safety goal should be developed regarding alarm system management (AAMI, 2011).

Alarm fatigue is the state in which nurses become overwhelmed by the sheer number of alarms, resulting in desensitization, which may lead to missed alarms or a delayed alarm response (ECRI, 2011). The presence of alarm fatigue can compromise patient safety if alarms, especially those associated with physiological monitors, are disabled, silenced, or ignored (Graham & Cvach, 2010). The literature highlights many factors which contribute to the development of alarm fatigue. Contributing factors include false alarms, technical alarms, inappropriate alarm limits and settings, and overutilization of physiological monitoring (ECRI Institute, 2007). The increased number of nuisance or low level alarms also plays a significant role (Phillips, 2006). Most alarms are due to rate violations, artifact, and insignificant arrhythmias (Piepenbrink, 2011). Frequent false or inconsequential alarms reduce the credibility of the alarm by causing distrust in the system. Users will perceive the system as less reliable if there are an increased number of false alarms (Sendelbach, 2012). Bliss, Gilson, and Deaton (1995) supported this finding with their observational study on alarm responses. The authors found that most subjects matched their alarm response to the expected probability of true alarms. A reduction in alarm reliability resulted in a reduced response.

A false alarm is an alarm which is detected by the monitoring system as indicating a physiologic event when no actual event occurs (ECRI, 2007). A nuisance alarm is defined as a clinically non-actionable alarm (Welch, 2011). The literature frequently interchanges these terms. Frequent false or nuisance alarms create distrust in the alarm system. According to Phillips (2006), alarm systems are almost useless when false alarm rates are high. A high frequency of false or nuisance alarms creates a 'cry wolf' environment where nurses assume from previous experiences that the alarm is likely a nuisance alarm and therefore do not respond appropriately (ECRI, 2007). Frequent false alarms may also lead nurses to disable alarms. A 2005 survey conducted by the HTF found that 78% of respondents agreed that they inappropriately disable alarm systems (Korniewicz, Clark, & David, 2008). This survey was repeated in 2011 with no significant improvement in results. Seventy-eight percent of respondents continue to inappropriately disable the alarms (HTF, 2011).

Two of the three observational studies reviewed highlighted the frequency of false or nuisance alarms. The first of these studies was a prospective observational study conducted in five ICUs in Northern France (Chambrin et al., 1999). The study included 131 patients and 246 observations, for a combined total of 1,971 hours of care. A total of 3,188 alarms occurred during the observations. However, only 5.9% of alarms led a nurse to call a physician for a possible intervention. Twenty four percent of alarms were due to staff manipulation, 17% were caused by technical problems, and 59% were due to the patient themselves. Of the 59% of alarms produced by the patient, 72% of these were transient and required no action (Chambrin et al., 1999). The second study was also a

prospective observational study. It was conducted on a nine bed coronary respiratory care unit in a Canadian hospital, and examined the implications of remote telemetry on nurses and patients (Billinghurst, Morgan, & Arthur, 2003). Critical care nurses in the unit were responsible for monitoring telemetry of patients on other units in the hospital. A total of 54 hours of data were collected. Billinghurst et al. (2003) found that 80.2% of warning arrhythmias were invalid or due to artifact.

Another more recent study continued to demonstrate a high frequency of false alarms. A retrospective alarm analysis was conducted by Gross, Dahl, & Nielsen (2011) in a community hospital in Arizona in order to qualify the patient monitoring alarm load for sub-acute medical and surgical floor patients. In this study, continuous physiological monitoring was initiated on 79 medical surgical beds within the hospital, and data was collected from April 2009 to January 2010. Remote telehealth center personnel received all alarms and were responsible for notification to the care providers. A randomly selected subset of 30 of the total 4,104 patients was chosen for review. In this sample, 34% and 63% of critical alarms and high priority alarms were true, respectively. Although this study illustrated improvement in the percentage of true alarms from the other studies, it still indicated that a significant number of false alarms occurred.

Technical alarms indicate that an operational aspect of the equipment requires attention. An example of a technical alarm is an ECG leads off alarm. Technical alarms, which are a low priority alarm on many systems, are frequently considered nuisance alarms and are a major cause of alarm desensitization (Bonzheim et al., 2011). However, certain technical alarms can have significant implications. For example, during a leads off

condition, the patient is unmonitored and a critical event, such as a potentially lethal arrhythmia, will not be detected. This type of situation is what prompted a failure modes and effect analysis (FMEA) at a Connecticut hospital. Semple and Dalessio (2004) conducted a FMEA to address response time to low level non-critical alarms, including the leads off alarm. Baseline monitoring revealed that the response time to non-critical alarms was 12 minutes. Several changes were implemented through the FMEA, including a reduction in nuisance alarms. For instance, they were able to decrease alarms that sound when the patient was off the unit by suspending monitoring. The implementation of this and other changes resulted in a decrease in response time to less than two minutes. The authors of this study recognized the importance of a prompt response to this particular technical alarm, which was also echoed in other articles reviewed. Phillips and Barnsteiner (2005) believed that a leads off alarm should be responded to with the same urgency as a three star cardiac alarm. In addition, Keller, Diefes, Graham, Meyers, and Pelczarski (2011) suggested that any institution's plan to address alarm management should include the need to elevate response priorities to critical alarms such as those identifying a leads off condition.

The literature offered suggestions for improving alarm management, as well as interventions to reduce false, technical, and nuisance alarms. Many interventions involved adjusting the default monitoring parameters. Graham and Cvach (2010) included changes to the low and high heart rate thresholds in their quality improvement initiative. The low heart rate threshold was reduced from 60 to 50, and the high rate was increased from 120 to 150. Welch (2011) presented the idea of decreasing pulse oximetry

alarm thresholds and introducing alarm delays in his retrospective alarm analysis. In a quality improvement project conducted at LeHigh Valley Medical Center, Harris et al. (2011) highlighted education as an essential avenue in addressing the problem. Central to all of the proposed interventions was that the first step was conducting a baseline assessment of the problem. For example, Graham and Cvach (2010) and Welch (2011) obtained baseline statistics by retrospectively reviewing alarm data obtained from central monitoring equipment. Harris et al. (2011) utilized informal observation to obtain their baseline figures. Semple and Dalessio (2004) completed their initial assessment by asking the unit educator, cardiology specialist, and an assistant director to observe and time nurse response to alarms over a three day period across all shifts before initiating changes during a FMEA. The strategies these authors used for the initial assessment of the problem are a form of risk assessment. The information obtained not only provided comparison data for interventions, but also highlighted the areas of greatest concern or risk.

Several articles focused on more extensive strategies for conducting an alarm risk assessment or alarm system safety evaluation. Richardson (2004) described a clinical alarm system testing program utilized at one large health care system in the United States. In this facility, two clinical alarm tests occurred each month. One of these tests was conducted on a unit based piece of equipment, such as an infusion pump. Any equipment which had an alarm could be included in the test. The test occurred on each unit that was currently utilizing the selected piece of equipment. A standardized, system wide form was utilized. The test evaluated for alarm response, and included various

questions related to risk assessment such as proximity of alarm, frequency, and staff member preparedness. If a high risk alarm, defined as an alarm which scored a value greater than eight on the observation form, was identified during the evaluation, an action plan was created to address the issue.

Other articles reviewed provided additional aspects to consider when conducting a risk assessment. Phillips (2006) suggested including questions that identify practices related to silencing and disabling, examination of unit culture on alarm response, and evaluation of how alarms are communicated in the unit, such as cell phones or pagers. Keller et al. (2011) presented their own ideas about important features of alarm assessment including discussion with staff about alarm related concerns and observations of how alarms are used and parameters are set in various areas of the hospital. Sendelbach (2012) recommended that periodic alarm surveillance should occur with a focus on the number of false alarms.

While the literature on alarm fatigue mounts, and the list of suggestions to address the problem continues to expand, there is still much more to understand and learn. Phillips (2006) identified that most studies regarding alarm fatigue have been conducted in critical care. Since 2006, additional work has been completed but has continued to focus on critical care or progressive care units. Less attention has been focused on general medical surgical units where the stakes may be higher. This increased risk is due to a higher patient to nurse ratio and the large size of these patient care areas. The architectural layout of most medical surgical units results in nurses frequently being a great distance from the central monitor location. In addition, the literature agrees that one

risk of alarm fatigue is a delayed response to alarms. However, there is no data regarding what constitutes a delayed response. Finally, the process for performing a risk assessment is highlighted as a strategy to improve alarm management. Even so, there is no standard method which is recommended or proven to be most effective.

Despite the gaps discussed above in the literature, there was consistency in the need to conduct an initial alarm assessment. This could be completed by obtaining baseline alarm data or by performing a formal alarm system evaluation. Conducting any type of initial evaluation not only provides information about the depth of the problem, but also highlights areas of greatest risk and provides data for comparison after interventions are initiated. The information obtained during this observational study will offer the administration of the study hospital a baseline assessment of alarm data and will serve as a risk assessment for the potential presence of alarm fatigue on the medical surgical units.

Next, the theoretical framework that guided this observational study will be presented.

Theoretical Framework

The Transactional Theory of Stress and Coping was the theoretical framework selected to guide this study. This theory provides an explanation for the psychological basis of alarm fatigue and supports the necessity for a study which quantifies the number of telemetry alarms, especially false and nuisance alarms.

Lazarus and Folkman (1984) defined stress as a relationship between the person and the environment that is appraised by the person as taxing or exceeding their resources. Based on this concept, stress has two major factors, the person-environment relationship and cognitive appraisals. The person-environment relationship includes beliefs, commitments, social supports, and demands and constraints. In regards to alarm fatigue, the environment is the clinical environment, the belief may be the unit culture related to alarm management practices, and the demands and constraints are all the responsibilities which are expected of nurses.

The three cognitive appraisals are primary, secondary, and reappraisal. Primary appraisal is the judgment an individual makes about an event (McEwen & Wills, 2011). A primary appraisal can be irrelevant, benign positive, and stressful. Stress appraisals include harm/loss, threat, or challenge. A threat is considered a harm or loss which has not yet taken place (Lazarus & Folkman, 1984). Secondary appraisal is the process by which an individual determines what coping options are available and how they will respond to the event or stressor. Lazarus and Folkman (1984) defined coping as "constantly changing cognitive and behavioral efforts to manage specific external and/or internal demands that are appraised as taxing or exceeding the resources of the person"

(p. 141). Emotion focused or problem focused coping are the two types of coping that occur (Lazarus and Folkman). Emotion focused coping changes the meaning of the situation. Problem focused coping changes the person-environment relationship. Reappraisal occurs once the person has coped with the situation, and allows for feedback about the outcome (McEwen & Wills, 2011).

When the theory is applied to the nurses' response to telemetry alarms, it offers insight into the thought process occurring when someone is experiencing alarm fatigue. A telemetry monitor alarm should alert the nurse to a possible issue with a patient and the nurse should respond. However, in a hospital environment where nurses have many responsibilities and the telemetry alarms are incessant, the nurse may begin to view the alarms as a threat to the time he or she needs to spend on other tasks. The primary appraisal is a stress appraisal; the alarms are seen as a threat. The secondary appraisal occurs when the nurse considers what he or she should do about the alarm. The nurse uses emotion focused coping to deal with the threat he or she perceives. The nurse changes the meaning of the alarm from something of importance to something insignificant and ignores the alarm or delays his or her response. The 'cry wolf' environment created by frequent false and nuisance alarms likely contributes to this response. Reappraisal occurs when the nurse reviews the alarms or checks on the patient and sees the outcome of his or her coping method. If there was no harm to the patient in the action of ignoring the alarm because it was insignificant, this perpetuates the cycle.

According to this theory, in order for alarms to have more significance to the nurse they must not be viewed as a threat to his or her time and resources. A reduction of

total telemetry alarms, especially false and nuisance alarms, would reduce the perception of threat. In an environment where alarms are less frequent, those alarms that do occur would be considered more significant. However, in order to implement interventions that would reduce total alarms, it is necessary to conduct an initial alarm assessment. This can be achieved with an observational study, such as was conducted by this researcher.

Methodology

Purpose

The purpose of this observational study was to collect and evaluate telemetry alarm data to answer the research question: Are medical-surgical nurses at risk for and experiencing alarm fatigue?

Design

The design of this study was a structured, non-participatory observation.

Sample/Site

The potential subjects were all nurses working on two medical-surgical units at an acute care hospital located in Providence, RI. The potential sample number was 75 nurses. The inclusion criteria consisted of all nurses employed as registered nurses at this facility working on the study units at the time of the observations. This included float nurses. The exclusion criteria included nursing students and clinical nurse interns. The sampling method was non-probability, convenience sampling.

Measurement

All observational data was collected utilizing a standardized observation form developed by the researcher. The original tool was adapted from forms utilized by Harris et al. (2011) with permission. Input was also obtained from the institution's Alarm Fatigue Committee. Though not tested for reliability or validity, the measure was piloted on two medical-surgical units not participating in the actual study, for one hour on each unit. The tool was adapted to its final version (Appendix A) as a result of the initial pilot

observations. The finalized version was pilot tested on the same units for an additional two hours.

Procedures

The researcher obtained approval from the Lifespan and Rhode Island College Institutional Review Boards (IRB) prior to beginning data collection. The Nursing Executive Council at the hospital also endorsed the study. In addition, managers on both study units provided a written agreement of participation.

During observations, the researcher was approached by staff nurses on several occasions. The researcher was truthful regarding the collection of telemetry alarm data, but did not discern the entire purpose of the observations. Telemetry activity was observed by the researcher at the central monitor in one hour blocks across the day, evening, and night shifts on both study units. The researcher was dressed in scrubs and located in front of the selected central monitor screen. During each observation, data was collected on a maximum of six monitor tracings from one screen of the central monitor area. The data collection tool included six columns, one for each potential monitor tracing, similar to that depicted in Table 1 (see Appendix A for complete Data Collection Tool).

Table 1

Sample Excerpt from Data Collection Form

Type	Description	Individual?	Response	Repeat	Comment

The monitor to be observed was selected at random at the start of each observation period. The researcher attempted to select a monitor which did not have multiple alarms in progress at the start of the observation. The monitor was utilized by the researcher to review monitoring parameters and alarm recordings. No alarms were silenced or acknowledged by the observer. The researcher recorded all alarms sounded for each telemetry monitor tracing selected. Alarms were classified as false, valid, or technical. This information was recorded in an abbreviated form in the column labeled *type*. Definitions for alarm classification were established based on the literature as follows:

- A false alarm was an alarm detected by the monitoring system as indicating a physiological event when no real event has occurred (ECRI, 2007). Examples of false alarms, from the literature, include motion artifact, improper detection of a P or T wave, and low perfusion during pulse oximetry monitoring.
- A valid alarm was "an alarm that represents true and accurate physiological data" (Welch, 2011, p. 49). It represents a true violation of set parameters. An actual alteration in heart rate, such as tachycardia, would represent a valid alarm.
- A technical alarm was an alarm to notify clinicians that an operational aspect of the system required attention. A leads off alarm was one example of a technical alarm.

The column labeled *response time* was used to record the length of time for critical and leads off alarms only. A critical alarm was a red, three star continuous alarm which required acknowledgement at the central monitor. A leads off alarm signified either one or all the monitoring leads had been removed or the telemetry box had been

disconnected from the patient. The researcher utilized two stop watches during each observation and timed the first two conditions which occurred consecutively. If a leads off alarm exceeded 10 minutes it was recorded at that time, to allow for timing of additional alarm conditions.

Additional columns on the observation tool included *description*, *individualization, repeat,* and *comments*. The *description* column was used for the label or name of the alarm, such as multiform PVCs, irregular heart rate, and pacer not pacing, as it appeared on the central monitor. The column labeled *individual* was for a yes or no response. The researcher evaluated if there was individualization of alarm parameters for each patient and recorded once as a yes or no. Alarms were considered individualized if any parameters had been changed from the default settings. Repeated alarms were tallied in the *repeat* column. This information was utilized during the analysis phase of the study. The *comments* column was for any additional information the researcher determined to be pertinent to record for later evaluation.

The researcher ensured protection of nurse subjects by not including any personal identifiers on the data collection tool. The only demographic data included on the tool was the number of RNs on duty. The researcher did not record any patient demographic data on the tool. The telemetry data was labeled by room number as it appeared on the monitor screen.

For the purposes of further protection, the date and time of observation were not recorded. As approved by the IRB, observation records were not shared with unit managers. If a critical event, such as undetected ventricular tachycardia, or any other life

threatening arrhythmia or condition occurred during observation, the researcher, an experienced critical care nurse, was able to recognize this. The goal of each observation was to observe without intervention. If no immediate response was noted at the central monitor, the researcher had developed an IRB approved plan to notify any available RN of the alarm to facilitate the patient receiving appropriate attention. This action was not needed, as this did not occur during the observation period.

Observations and data collection continued until a pattern of redundancy was noted. A total of six hours and two minutes of observations occurred over a period of six weeks. One observation per shift on each study unit was completed by the researcher.

Data Analysis

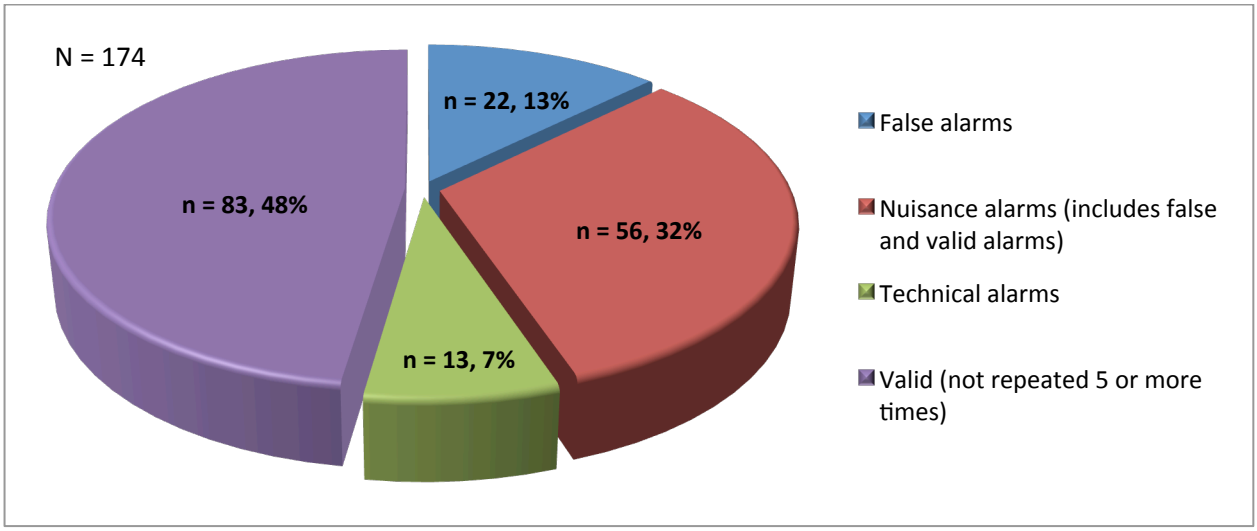
The researcher combined all data from each observation to create one complete data set. First, each observation was reviewed separately to calculate the number of nuisance alarms and the percentage of telemetry monitor tracings with individualized alarm parameters. For the purposes of the study, the researcher has defined a nuisance alarm as any false, technical, or valid alarm which is repeated five or more times during the one hour observation period. The complete data set included: an aggregate of all alarms sounded; total number and percentage of false, technical, nuisance, and valid alarms; and the average percentage of telemetry monitor tracings with alarm parameters individualized. The mean response time to critical and leads off alarms was calculated and included on the data set as well. Alarm frequency was recorded, and was calculated as the total minutes of observations divided by the total number of alarms.

Results

The total observation time was 362 minutes involving 36 nurses. Observations occurred across the day, evening, and night shifts on both study units. During that time, 174 telemetry alarms occurred on the selected monitors. One alarm occurred approximately every 2.08 minutes. There were 22 false alarms, 56 nuisance alarms, 13 technical alarms, and 83 valid alarms. Table 2 illustrates the percentage of each type of alarm.

Table 2

Total Observed Alarms by type



*Any alarm became a nuisance alarm once it was repeated more than four times.

A total of three critical alarms occurred, two of which were false. Response time to the critical alarms ranged from 2.6 seconds to 10.2 seconds. The mean response time was six seconds. A total of eight leads off, including transmitter off, conditions occurred.

The mean response to a leads off condition was 7.01 minutes. Response time, ranged from 1 minute and 20 seconds to greater than 10 minutes. Five out of eight response times were greater than 10 minutes. Rate violations, both above and below the set parameters, accounted for 43 of the alarms. Fifty-three of the total alarms were related to premature ventricular contractions (PVCs), including paired PVCs, multiform PVCs, and greater than 10 PVCs per minute. Thirty five alarms were due to an irregular heart rate; in 28 of these alarms, the researcher noted the monitor pattern was atrial fibrillation.

Summary and Conclusions

Summary

The ECRI Institute, a federally designated patient safety organization, identified alarm hazards as the number one health technology hazard in 2012, recognizing that alarms have been attributed to the occurrence of many adverse patient events (ECRI Institute, 2011). Alarm fatigue is the phenomenon which occurs when nurses become overwhelmed by the high number of alarms in the clinical environment (ECRI, 2011). The presence of alarm fatigue can compromise patient safety if alarms, especially those associated with physiological monitors, are disabled, silenced, or ignored (Graham & Cvach, 2010). The literature highlights many factors which contribute to this phenomenon including false alarms, technical alarms, inappropriate alarm limits and settings, and overutilization of physiological monitoring (ECRI Institute, 2007). The increased number of nuisance or low level alarms also plays a significant role (Phillips, 2006).

Frequent false or inconsequential alarms reduce the credibility of the alarm by causing distrust in the system. A high frequency of false or nuisance alarms creates a 'cry wolf' environment where nurses assume from previous experiences that the alarm is likely a nuisance alarm and therefore do not respond appropriately (ECRI, 2007). Frequent false alarms may also lead nurses to disable alarms. A 2005 survey conducted by the HTF found that 78% of respondents agreed that they inappropriately disable alarm systems (Korniewicz et al., 2008). The survey was repeated in 2011 with no significant

improvement in results. Seventy-eight percent of respondents continued to inappropriately disable the alarms (HTF, 2011).

TJC has proposed that in 2013 a new National Patient Safety Goal should be developed regarding alarm system management (AAMI, 2011). Therefore, it will be an expectation that all TJC certified hospitals are actively addressing alarm system safety. In order to develop effective interventions, initial and ongoing assessments of the problem will need to occur. The purpose of the observational study was to collect and evaluate telemetry alarm data to answer the research question: Are medical-surgical nurses at risk for and experiencing alarm fatigue? The data collected will serve as a baseline risk assessment of the problem at the study site.

Conclusions

Telemetry alarm data was collected over a six week period on two medical-surgical units at an acute care teaching hospital in Providence, RI. Data were analyzed to determine if nurses were at risk for and experiencing alarm fatigue. The researcher found that nurses at the facility are indeed at risk for alarm fatigue. Alarms occurred frequently, approximately every two minutes, and 52% of alarms were false, technical, or nuisance alarms, which are known, contributing factors to alarm fatigue. Piepenbrink (2011) reported that most alarms are due to rate violations, artifact, and insignificant arrhythmias. Results in the study were consistent with these findings: more than 70% of the alarms observed were due to potentially insignificant arrhythmias (PVCs and irregular heart rate) and rate violations. Many of the alarms may have been avoided with appropriately set parameters, including setting the PVC frequency alarm higher in the

presence of known, chronic PVCs, and disabling the irregular heart rate alarm for patients who were in atrial fibrillation. The high frequency of alarms, as well as the increased number of inconsequential or false alarms, contributes to the desensitization which is characteristic of alarm fatigue.

Less than half of the total alarms observed were valid. Bliss and colleagues (1995) found that subjects, in their study, matched their alarm response to the expected probability of true alarms. Data from the study revealed that only 48% of alarms were valid; therefore it could be expected, based on the work by Bliss et al. (1995), that nurses would respond to alarms approximately half the time. If the nurses perceived the system to only represent a true event in 48% of the situations, they would match their response and potentially ignore true and significant alarms. The high amount of false and nuisance alarms which occurred, 45%, contribute to the 'cry wolf' environment where nurses ignore or delay their response due to the belief that the alarm is false or inconsequential.

Nurses on the study units were not only at risk for alarm fatigue, they were experiencing it, as evidenced by a delayed response to leads off alarm conditions. For purposes of the study, a delayed response was defined as greater than three minutes, inferred by the researcher based on literature related to cardiac arrest. The mean response time to a leads off condition was 7.01 minutes. The ECRI Institute (2007) cited leads off alarms as the cause of multiple deaths resulting from cardiac events which were not detected due to this condition. During a leads off condition, identification of a potentially lethal arrhythmia, such as ventricular fibrillation, will not occur. According to the AHA (2010), during in-hospital cardiac arrest, the time to shock for a patient experiencing

ventricular fibrillation should be less than three minutes. Although all arrest rhythms are not appropriate for defibrillation, rapid recognition is necessary to initiate early cardiopulmonary resuscitation (CPR). Each minute without CPR after cardiac arrest decrease the chances of survival by 10-15% (Lira and Sinert, 2011). According to a FMEA conducted by Semple and Dalessio (2004), 12 minutes was the average response to non-critical alarms during initial data collection. The delayed response to leads off conditions demonstrated in this study was consistent with the literature.

Conversely, nurses did not exhibit a delayed response to critical alarms. Nurses responded to critical alarms quickly; the average time was six seconds. This may be at least partially related to the sound produced by such alarms. A critical alarm is a loud, continuous ringing which requires acknowledgment at the central monitor in order to be stopped. This is much different than the low, continuous tone emitted when a leads off condition exists. The leads off alarm will also continue to sound until the issue is corrected; however, the signal produced is not nearly as concerning as the critical alarm signal, and therefore it may not demand immediate attention.

Limitations

There were several limitations to the study. First, the total observation time was limited to six hours and six observations, a lesser quantity of time compared to other observational studies. Billinghurst et al. (2003) collected 54 hours of data and Chambrin et al. (1999) conducted 246 observations. A second limitation was the capability of the researcher to observe a maximum of six telemetry tracings. During each observation period, there were either one or two central monitors with additional telemetry tracings

that were not included in the study. Of note, the researcher does recall that there were many other alarm conditions, including critical alarms and leads off alarms, which occurred on monitors not being observed as part of the study. The additional alarms likely would have provided further valuable data, as well as increased total alarm frequency. A third limitation was the potential for behavioral changes related to the Hawthorne effect. The status of the researcher as an employee at the study site made it difficult to remain inconspicuous during observations. Nurses, as well as other health care providers, recognized and questioned the presence of the researcher on the study units. The impact of the researcher being present is not clear, but a significant impact is not likely given the findings.

Recommendations for the institution

The risk assessment demonstrated the need for the study facility to promptly implement strategies to address alarm fatigue. The researcher expected that the organization would be susceptible to a problem which plaques healthcare facilities across the country. The findings of this study and recommendations for practice improvement will be provided to the institution's Alarm Fatigue Committee.

Several areas for intervention have been identified. First, all nursing staff need to be aware of the presence of alarm fatigue on medical surgical units and the impact on patient safety. Second, nursing policies related to telemetry monitoring will need to be addressed. Currently, the telemetry policies at the study institution do not address response time or the role of the nurse regarding telemetry when a patient is off the unit, for example to undergo testing. The updated policy should reflect the importance of

placing a monitoring device on standby in such cases. This would likely aid in reducing the number of leads off conditions and potentially eliminate the presence of false alarms created by intentional discontinuation of monitoring by nurses. The practice of placing the monitor in standby mode resulted in a significant decrease in response time to low level alarms in a FMEA conducted by Semple and Dalessio (2004). Nurses will need to be oriented to the revised policies, which will make them more accountable for their practices regarding telemetry monitoring.

Continued education regarding alarm management and individualization is needed. Annual competency assessments and training related to alarm management should be mandated. Many nuisance alarms, as well as some false alarms, could have been avoided with appropriately set monitoring parameters. For example, if a patient is in atrial fibrillation, the nurse could disable the irregular heart rate alarm. Alarm management training might be best taught by representatives of Phillips, the telemetry equipment manufacturer, as they would be most comfortable with all the nuances of the equipment. However, a more feasible and long term solution would utilize hospital educators who have received the appropriate training. The study facility has begun to offer voluntary alarm management classes periodically, but should consider the value of making the practice consistent.

Finally, it is essential that the study facility recognizes that this initial risk assessment should not be the only alarm system evaluation that occurs. Ongoing assessment will be necessary to determine if interventions are effective. The assessment may be in the form of formal observation such as the one discussed here, or an informal

process carried out by a unit manager, staff nurse, or advanced practice nurse (APRN), such as a clinical nurse specialist (CNS).

Next, implications and recommendations will be discussed.

Implications and Recommendations

In April 2013, TJC issued a sentinel event alert about medical device alarm safety citing alarm fatigue as a major contributing factor. The alert confirmed the magnitude of the problem, as well as identified the importance of healthcare organizations implementing interventions swiftly to address this significant patient safety issue. In addition, alarm fatigue continues to receive mainstream media attention that highlights the risk, primarily death and injury, associated with the presence of this phenomenon. As healthcare becomes increasingly transparent and healthcare consumers more knowledgeable, it is only a matter of time before patients and families start to ask the nurses and doctors what is being done to address the problem.

It is imperative that each individual organization creates a task force to manage the issue. This group should include an inter-disciplinary representation of all important stakeholders within the institution, including administration, nursing, risk management, and biomedical engineering. An APRN would also be a valuable asset to this group. The focus of the group should include collecting alarm data regarding alarm frequency, response, and nursing alarm management practices. The committee should also implement practical solutions such as education, policy revision, and updating equipment which is outdated or ineffective. However, the problem cannot be solved at an organization level alone. The development of the best possible solutions to eradicate alarm fatigue will take time and will require an interdisciplinary collaborative effort between safety organizations such as TJC, alarm manufacturers, and health care organizations.

Alarm manufacturers will need to be cognizant of concept of alarm fatigue at the level of alarm system design. It will be necessary for manufacturers to build in safeguards which help reduce unnecessary alarms, produce systems which are more intuitive as well as user friendly, and make sure that certain alarms are given the appropriate sounds consistent with the level of priority. For example, the alarm produced during a leads off condition should more appropriately reflect the risks associated with it. The alarm should sound similar to a critical alarm so that it receives prompt attention, a suggestion supported in the literature. A leads off alarm should be responded to with the same urgency as a three star cardiac alarm (Phillips & Barnsteiner, 2005); a three star cardiac alarm is the highest priority alarm and occurs with emergent conditions such as ventricular tachycardia. This is an area where further research, as well as input from healthcare organizations, would be invaluable. As the front line users of the equipment, nurses and APRNs could assist in the design process and create alarms which are practical as well as effective. Additionally, manufacturers should be willing to provide continued education to hospitals annually as a benefit of utilizing their equipment. This would facilitate the monitoring equipment being used to its highest capacity and ensure consistency of use.

The development of a national patient safety goal regarding alarm management by TJC is an important step in eliminating alarm fatigue. Since reimbursement by government organizations such as Medicare requires TJC accreditation, all hospitals will need to demonstrate active efforts to address this problem. If many organizations are developing solutions, imagine the power of bringing all of these hospitals or healthcare

networks together. In 2011, a symposium such as this occurred. The 2011 Alarm Summit was a collaborative effort between the Food and Drug Administration (FDA), AAMI, ECRI Institute, TJC, and the American College of Clinical Engineering (ACCE). Several institutions, such as Boston Medical Center, were highlighted as leaders in addressing alarm fatigue. The document, published by the AAMI after the Summit, provided an extensive list of areas which required attention in order to eliminate alarm fatigue, but more importantly it recognized the need for a collaborative effort amongst all stakeholders. Similar meetings need to happen regularly in order to eliminate alarm fatigue.

APRNs can be a valuable resource at an organizational level as active members of an alarm fatigue taskforce. The APRN could serve as an expert in designing and implementing a research study or quality improvement project to identify educational needs, determine the most effective default monitor settings for a particular unit, or conduct an observational study such as the one discussed here to identify the most problematic areas. The APRN could also assist in policy revision. A cardiac nurse practitioner might be useful in identifying parameters which are appropriate for ordering telemetry, thus reducing unnecessary monitoring which is known to contribute to alarm fatigue. Additionally, a CNS could assist in education regarding alarm management or be involved in the process of regular alarm system evaluation.

However, the role of the APRN could extend well beyond the individual organization. The advanced practice nurse would be an ideal team member to any other organization involved in developing solutions for alarm fatigue including the TJC, FDA,

or an alarm system manufacturer such as Phillips. The APRN could also be invaluable in impacting health care policy through lobbying efforts and involvement in key policy making institutions.

The most effective solutions for alarm fatigue will be research and evidenced based solutions. Healthcare organizations will be responsible for selecting the most appropriate strategies for their institution. Approaches should include structured research studies as well as a thorough analysis of current evidence. Evidence based practice committees could be useful in conducting reviews of literature to address concerns such as whether alarms which count PVCs are clinically relevant. Research studies could be utilized to determine best practices to reduce false alarms, with one unit acting as a control and a sister unit acting as the experimental group. The research would ensure only the most effective strategies were rolled out to the entire institution.

Overall, there is a lack of true experimental studies related to alarm fatigue, which may be due to the nature of healthcare and the difficulty in attempting to maintain control over a clinical environment required in such a study design. Reducing the number of false and nuisance alarms may be an area appropriate for alarm system designers to research. The APRN could be useful by offering expertise in the use of simulation for safe alarm system experimentation and testing. Monitoring equipment manufacturers might be able to develop experimental studies to determine appropriate alarm signal tones, volumes, threshold settings, and other configurations in order to create systems which are more effective. Alarm fatigue, although a newly coined phenomena, has been recognized as an issue for more than a decade and will likely take years to completely

eliminate. Efforts by all stakeholders are essential immediately if we are to assure that patients will not continue to be harmed by adverse alarm events. Alarm fatigue represents a national issue that directly impacts the health of the population overall. Nurses, especially APRNs, need to be at the forefront, leading efforts to assure this public health challenge is swiftly and effectively addressed.

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Appendix A

Data Collection Tool

Observation #: Length of Observation: Unit: RNs: Patient Census:

ype	Description	Individual?	Response	Repeat	Comment	Type	Description	Individual?	Response	Repeat	Comment
ype	Description	Individual?	Response	Repeat	Comment	Type	Description	Individual?	Response	Repeat	Comment
ype	Description	Individual?	Response	Repeat	Comment	Type	Description	Individual?	Response	Repeat	Comment

Type: (F)alse, (T)echnical, (V)alid
Description: label on alarm
Individual?: are settings individualized?
Response: respone time for leads off and critical alarms
Repeat: note if alarm is repeated
Comment: additional information