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Identifying Nurse's Perspectives and Practices about Clinical Monitor Alarm Burden and Alarm Fatigue.

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DNP Final Project Report

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Dedication

This project is dedicated to all my dear friends. Thank you for your patience, grace, and longsuffering. I know I missed out on some stuff but thanks for understanding. You guys always knew when to let me "bow out" and when I really needed to be pried away from the schoolwork. You listened, you kept me sane, and you made this project possible with your loving encouragement. This project is also dedicated to all alarm fatigued nurses out there (I get it people) and of course for the few of us that just can't ignore that infernal beeping.

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Abstract

PURPOSE: To obtain insight into the nursing culture of the University of Kentucky Medical Center (UKMC) regarding alarm fatigue, measure nuisance alarm events, and identify the practices nurses at UKMC engage in to manage alarm pollution and mitigate alarm burden. Moreover, this practice improvement project identified how innovations like the introduction of a monitor watcher has impacted the rates of nuisance alarms and influenced nursing culture.

METHODS: An online survey based on the 2011 Healthcare Technology Foundation Alarms Survey (HTF) was sent to nurses in two intensive care units at UK Healthcare (UKHC). The results of the 2017 UKHC Alarm Survey were compared to published studies that used a similar version of the 2011 HTF Alarms Survey. Also, alarm events were recorded and categorized based on frequency and type to assess the number of nuisance alarms present in each unit.

RESULTS: Survey results found in published studies were like those found at UK Healthcare with an exception noted that UKHC nurses reported lower agreement scores when asked about the helpfulness of a monitor watcher. Repetitive and clinically irrelevant alarms (ECG nuisance alarms) made up about a third of all alarm events recorded at UKHC and these numbers were unaffected by the attendance of a monitor watcher. Also gaps in nursing education related to alarm management issues were identified.

CONCLUSION: Interventions such as the routine deactivation of repetitive and clinically irrelevant alarms may result in a lessening of the factors that contribute to the development of alarm fatigue. Hospital policies must be updated to encourage customization of alarms with special attention being given to efforts that reduce nuisance alarms. Education gaps can be addressed by a standardized approach to the education of all nurses who work with clinical monitors.

Identifying Nurse's Perspectives and Practices about Clinical Monitor Alarm Burden and Alarm Fatigue.

Introduction

Clinical monitors are used in every intensive care unit throughout the world and provide valuable information to help diagnose and guide the treatment of acutely ill patients. Clinical monitors record patient variables like heart rate, blood pressure, respiratory rate, pulse oximetry, dysrhythmias, and many other parameters. Clinicians use the information gathered from clinical monitors to help diagnose patient conditions like hypotension, hypoxia, and dysrhythmias. Moreover, readings from clinical monitors allow clinicians to see each patient's response to treatments like blood pressure medications, oxygen therapies, and many other patient specific treatments. Clearly, providers rely heavily on the readings obtained from clinical monitors to make care decisions and guide treatment. However, these systems are often troubled with frequent false and clinically irrelevant alarms that provide inaccurate data and distract care providers from real patient conditions (Colton et al., 2013; ECRI Institute, 2014; Siebig et al., 2010; Varpio, Kuziemsky, MacDonald, & King, 2012).

Inaccurate measurements, distracting alarms, and nonactionable alerts contribute to the development of alarm fatigue and this can lead to unsafe practices by bedside providers (Gazarian, 2014; Korniewicz, Clark, & David, 2008; Varpio et al., 2012). Alarm fatigue occurs when the repeated activation of alarms overwhelms a care provider to the point that they are forced to ignore or adjust alarms in potentially unsafe ways (Cvach et al., 2015; Sendelbach & Funk, 2013; Sendelbach, Wahl, Anthony, & Shotts, 2015). According to Sendelbach and Funk (2013), and Ulrich (2013) the diagnosis of some patient conditions can be delayed or missed due to monitoring errors or omissions, and this may allow patient conditions to go unnoticed until the problem is at a crisis level. Moreover, unanswered alarms have been linked to sentinel events

such as unnoticed patient decline, and in 2013 Ulrich reported that alarm related sentinel events result in death of the patient 80% of the time. Nurses who care for patients in areas where clinical monitors are used experience high levels of alarm pollution and alarm burden (ECRI Institute, 2014; Gazarian, 2014; Sendelbach & Funk, 2013; Siebig et al., 2010). The degree of alarm fatigue a care provider experiences is highly dependent on nursing culture, and the current alarm management practices of their unique care environment (ECRI Institute, 2014; Healthcare Technology Foundation, 2006; Korniewicz et al., 2008; Purbaugh, 2014; Sendelbach & Funk, 2013). High alarm burden and the development of alarm fatigue pose significant safety risks for patients who require clinical monitoring.

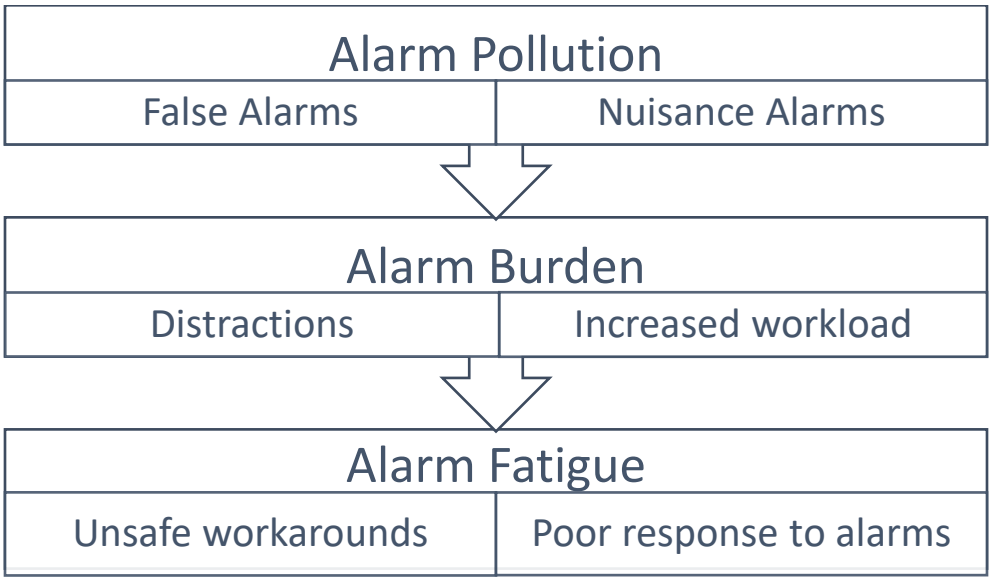

Fig 1. Factors that influence the development of alarm fatigue.

Background

Efforts to improve alarm safety and raise awareness of the problem of alarm fatigue and alarm safety are fueled by multiple organizations like the Federal Drug Administration (FDA), the Emergency Care and Research Institute (ECRI), the Healthcare Technology Foundation

(HTF), the Association for the Advancement of Medical Instrumentation (AAMI), and the American Association of Critical-Care Nurses (AACN). These organizations have worked to identify and find solutions to persistent problems with alarm safety. Researchers have created multidisciplinary organizations like the HTF to improve the safe use of technology in healthcare. In an attempt to understand the complexities of the issues surrounding alarm management, the HTF administered a national online survey on alarms in 2004/2005 (Korniewicz et al., 2008), and repeated the survey in 2011 (Honan et al., 2015). Furthermore, the ECRI, the HTF , and the AAMI have released handbooks and toolkits to assist hospitals in approaching the issue of alarm fatigue (ECRI Institute, 2014). These handbooks detail practices to reduce alarm fatigue such as changing ECG leads and pulse oximetry probes, updating clinical monitoring equipment, and customizing alarm parameters (Burgess, Herdman, Berg, Feaster, & Hebsur, 2009; ECRI Institute, 2014; Korniewicz et al., 2008). Although these organizations have issued recommendations many hospitals and bedside nurses still struggle with high levels of alarm burden and alarm fatigue.

Although alarm safety should be a priority to healthcare organizations, most hospitals have very few polices or resources available to assist bedside providers to reduce alarm pollution and manage alarm burden. The results from the 2011 HTF National Alarms Survey reflected very little change in nursing perspectives despite the efforts of various governing bodies including the Joint Commission (Funk, Clark, Bauld, Ott, & Coss, 2014), the ERCI, and the AAMI. From January 2005 to December 2010, 216 alarm related deaths were reported to the Food and Drug Administration (ECRI Institute, 2014). Alarm related safety concerns persist, and healthcare organizations must act to improve the safe use of clinical alarm systems. Although it may seem clear that action is warranted, alarm fatigue is a complex issue that

requires hospital administrators to carefully evaluate their unique environment to promote lasting change.

To tackle the problem of alarm fatigue hospital administrators must first begin to understand the practices and perspectives of the nurses in their institution. The consensus among organizations like the ECRI, the AAMI, the HTF, and the Joint Commission (TJC) is that hospitals should begin the process of change by doing an assessment of the current belief and practices with regard to alarms at their organization (ECRI Institute, 2014; Healthcare Technology Foundation, 2006; Welch, 2011). To that end, and to be in accordance with the national recommendations from the TJC, in 2013 the University of Kentucky Medical Center (UKMC) begin a review of its alarm culture, practices, and policies.

As part of this cultural and practice assessment UKHC invited the ECRI to complete a prospective patient safety review of alarm management focusing on physiologic monitoring systems. Key findings from the report included a lack of ownership of alarms, a pervasive problem with alarm fatigue, a lack of awareness of alarm related hospital polices/protocols, and a lack of metrics to track adherence to the hospital's alarm management practices. By the end of 2014 the work of cultural change, technology upgrade, policy revision, and staff education had begun at UKHC. This effort also included the addition of a monitor watcher to the Cardiovascular Intensive Care Unit (CVICU), a unit that was highlighted by the ECRI report as having a problem with alarm fatigue and alarm accountability. Although efforts to address the key findings of the ECRI report had begun, an evaluation of these initial interventions on perceived alarm fatigue and alarm burden was required.

The conceptual framework used in this study is based on Rogers's diffusion of innovations theory. The six stages of the diffusion process include innovation development,

adoption, implementation, maintenance, sustainability, and institutionalization. One focus of this project is to evaluate the adoption and institutionalization phase of adding monitor watchers into the ICU environment. Additionally, this project explores methods that may improve maintenance and sustainability of current alarm management practices. To that end, this practice inquiry project has been designed to evaluate nursing culture, record alarm rates, and identify areas that could be targeted for improvement at the UKMC.

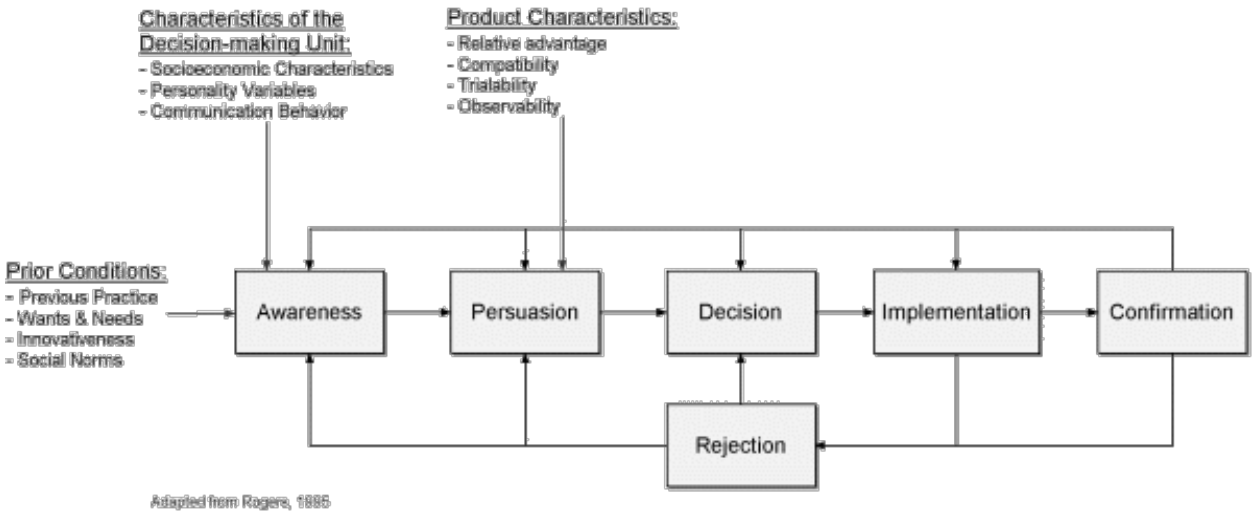

Fig 2. Rogers's diffusion of innovation theory.

Purpose

The goals of this study are to obtain insight into the nursing culture of UKMC regarding alarm fatigue, measure nuisance alarm events, and identify the practices nurses at UKMC engage in to manage alarm pollution and mitigate alarm burden. Moreover, this practice improvement project will identify how innovations like the introduction of a monitor watcher has impacted the rates of nuisance alarms and nursing culture in the sampled units. This project hopes to meet the following objectives:

1) Identify the nurses' perspectives and practices with regard to clinical monitor alarms at the UKMC and compare these results to the perspectives and practices of nurses surveyed in published studies.
2) Compare the perspectives and practices of nurses using clinical alarm systems in units with and without a monitor watcher.
3) Compare the total number, and type of alarms that occur over a seven-day period in units with and without a monitor watcher.

Methods

This project is a quantitative prospective cross-sectional study designed to understand alarm management perspectives and practices of nurses who work in the selected sample units. A version of the 2011 HTF Alarms Survey entitled "The 2017 UK HealthCare Alarm Survey" was developed and distributed to nurses in the 10th Floor Medical Intensive Care Unit (MICU),a unit without a monitor watcher and the 8th Floor Cardiovascular Intensive Care Unit (CVICU) a unit with a monitor watcher. Additionally, the types and frequency of alarms were recorded to measure alarm burden in terms of nuisance alarm events.

Setting

To meet the objectives of this project, two sample sets were included. The first section was a convenience sample of nurses working in the 10th floor MICU, and 8th Floor CVICU. This sample set consisted of full or part time staff nurses working in direct patient care in the designated units. The second sample set included alarms data downloaded from the Phillips server for 16 beds of the 10th floor MICU, and CVICU respectively**.** Alarm event data were downloaded from a central server into Excel software for 32 bedside monitors, 16 in each unit

selected. Alarm event data were collected for a random seven-day period during the survey window.

Sample

Sample selection for this study was based on the following principals and conditions. According to the HTF and the ERCI, the highest rates of alarm pollution and alarm burden are experienced by nurses in the critical care environment (ECRI Institute, 2014; Healthcare Technology Foundation, 2006). Moreover, researcher have theorized that alarm pollution and alarm burden may be mitigated when a dedicated monitor watcher is used to share the workload of alarm management and response (Healthcare Technology Foundation, 2006; Korniewicz et al., 2008; Sendelbach & Funk, 2013). For the purposes of this project, sample selection was narrowed to include only nurses in the ICU environment. Specifically, I chose the 10th floor MICU which does not have a dedicated monitor watcher, and the 8th floor CVICU, which uses two trained monitor watchers via a central monitoring station. Permission to use each unit in the study was granted by each patient care manager independently.

For the survey portion of this project, subjects were recruited via UKHC email addresses. No identifying data were collected other than years of experience in nursing and place of employment, i.e. what unit the nurse worked in. An invitation to participate in the survey was sent to all part and full-time nurses working in the 10th floor MICU, and 8th floor CVICU via employee email addresses provided by the director of each unit (approx. 300). The PI attended staff meetings and created flyers to engage and educate nurses on the purpose of the study. In addition, digital records of alarm data were downloaded into Excel software. The information recruited from digital records is location specific, and only information from the above listed bed locations was used for analysis.

Features

The available literature on alarm fatigue was reviewed for this project. A CINAHL search was conducted using the keyword "alarm survey," and 19 articles were found. Two published articles were chosen for review and comparison. One study was done on a national level and the second was conducted at a single hospital. Both studies used a version of the 2011 HTF Alarms Survey and both were administered in the acute care setting. As an assessment tool, the 2011 HTF alarm survey has qualities that make it useful in practice. The HTF survey possesses the following psychometric properties. According to DeVon et al. (2007), content validity can be established when a panel of experts agree that the items listed in the tool correctly obtain the information needed to measure the construct. In the case of the HTF alarms survey, it was evaluated by a 16-member task force made up of experts in the fields of nursing, biomedical engineering, and patient safety (Healthcare Technology Foundation, 2006). Moreover, this survey tool is considered reliable as it has been conducted nationally on three separate occasions each time yielding similar results (Clark, 2017; DeVon et al., 2007). Clearly this survey tool has an identified record of content validity and reliability.

Data Collection

Quantitative data were collected using an online survey tool which was administered to nurses in the selected units. A link to the 2017 UK HealthCare Alarm Survey was sent via secure email to nurses working in the 10th floor MICU and 8th floor CVICU of UKMC. The electronic survey was open for responses form October 30th 2017 to November 12th 2017. On November 8th 2017 data were downloaded from the clinical monitors.

Data Analysis

The 2017 UK HealthCare Alarm Survey asked participants to rate their level of agreement to several statements about alarm perceptions and practices. Percentages were based on a combined total of the responses of "Strongly Agree" and "Agree." These percentages were further grouped into level of agreement categories. Level of agreement percentages were also based on the number of respondents that answered, "Strongly Agree" and "Agree." Very high agreement percentages were assigned when greater than 90% of respondents gave "Strongly Agree" and Agree," high and majority agreement were assigned when 66%-89% gave "Strongly Agree" and "Agree." When agreement scores were low they were grouped as low agreement (33-49%), and very low agreement (<33%). Data were then analyzed using SPSS software and an independent sample T-test was used to find differences in agreement percentages based on unit worked in.

Alarm event data were directly downloaded and analyzed using Excel software, and organized by the types and frequency of alarm events. These data were grouped into four general categories and complied by frequency for comparison. This data collection process enabled appreciation of the rates of alarm pollution (nuisance alarms) and the level of alarm burden.

Results

A review of the current literature revealed several studies that attempt to assess alarm fatigue, and for the purposes of this project, two published studies that use the 2011 HTF Alarms Survey were chosen for comparison. At the completion of the 2017 UK HealthCare Alarm Survey responses were compiled as overall totals and totals based on unit worked. These results are reported as a comparison to nationally administered (The 2011 National Alarms Survey) and

single site administered (The 2015 Assessment of Clinical Alarms and the 2017 UK HealthCare Alarm Survey) surveys.

The 2017 UK HealthCare Alarm Survey received 106 completed surveys and respondents were categorized based on working environment. Survey respondents were divided into two groups, the 10th floor sample is made up of nurses working in a MICU that does not use a dedicated monitor watcher, and the second sample was obtained from the 8th Floor CVICU which uses a dedicated monitor watcher. The 10th floor sample contained 47 RN's, with 81% of respondents reporting less than 11 years of experience and the majority (51%) with less than five years of experience. The 8th floor sample contained 59 RNs; one respondent did not answer the "years of experience" question (n=58). In the 8th floor sample 93% reported less than 11 years of experience and 74% had less than five years of experience.

Very High Agreement Percentages

The 2017 UK HealthCare Alarm Survey reports very high agreement percentages (>90%) with several survey questions when compared to previously published national and single site studies. Very high agreement percentages were present in the UK HealthCare survey when participants were asked if nuisance alarms occur frequently (94%), disrupt care (91%) and reduce trust (95%). These results are similar to those found in the 2015 Assessment of Clinical Alarms which reports very high agreement with two questions 96% (disrupt care) and 100% (reduce trust;(Petersen & Costanzo, 2017). When the 2017 UK HealthCare survey results are divided by unit, both groups expressed a very high level of agreement when asked if nuisance alarms occur frequently (91% 10th floor, 97% 8th floor) and if nuisance alarms cause distrust (100% 10th floor, 92% 8th floor). Also nurses in the unit with a monitor watcher expressed very high agreement when asked if nuisance alarms disrupt care (93% 8th floor) and if alarm pollution

rates are high (92%, 8th floor). Moreover, UK HealthCare nurses reported very high agreement percentages when asked if their institution requires documentation of alarm limits. Although very high agreement percentages were found on some survey questions, the bulk of the survey responses reported high agreement and majority agreement percentages.

High and Majority Agreement

High agreement (66% to 89%) and majority agreement (50-65%) percentages were reported by most respondents when survey results are compared across published studies and the 2017 UK HealthCare Alarm Survey. According to the 2011 National Alarms Survey, high agreement percentages were found when national respondents were asked if nuisance alarms occur frequently (76%), disrupt care (71%), and reduce trust in monitoring equipment (78%) (Funk et al., 2014). Moreover, high agreement percentages (77% 10th floor, 83% 8th floor) were found when UK HealthCare respondents were asked if alarm burden was high. When asked if alarms were adequate to alert them to actual or potential changes in patient conditions, participants in all published studies (72%, 2011;73% 2015) and both units of the UK HealthCare survey reported high agreement (79%, 10th floor; 68%, 8th floor).

Staff sensitivity to alarms, difficultly determining alarm source and background interference statements reveal high and majority agreement in both the 2011 National Alarms Survey (Funk et al., 2014) and the 2017 UK HealthCare survey. The 2015 Assessment of Clinical Alarms survey showed majority agreement to statements concerning staff sensitivity (54%) and difficultly determining alarm sources (58%) (Petersen & Costanzo, 2017). Notably, "frequency of missed alarms" was reported as majority agreement in the UK HealthCare survey unit without a monitor watcher (59%, 10th floor). Moreover, statements regarding the usefulness

of smart alarms to improve alarm management showed high and majority percentages in both published studies as well as the 2017 UK HealthCare Alarm Survey.

When asked about potential solutions to alarm management problems, survey respondents in published studies continued to show high or majority percentages. Among participants in both the 2011 National Alarms Survey and the 2015 Assessment of Clinical Alarms surveys, high and majority agreement were shown to questions about the effective use of policies and procedures in their facility (Funk et al., 2014; Petersen & Costanzo, 2017). Additionally, published survey results showed high and majority percentages when asked if monitor watchers were useful (53%, 2011; 84%, 2015) and both published studies (56%, 2011; 81%, 2015) as well as the 2017 UK HealthCare Alarm Survey (60%, 10th floor; 56%, 8th floor) report high or majority agreement when asked if wireless devices such as pagers and cell phones were useful to relate alarm information (Funk et al., 2014; Petersen & Costanzo, 2017). Although most survey questions showed high or majority agreement results, a few questions indicated low and very low agreement percentages.

Low Agreement and Very Low Agreement Percentages

Low agreement (33-49%), and very low (<33%) agreement percentages were seen on questions related to the use of newer monitors, and the difficulty of setting alarms properly. Both published studies as well as the 2017 UK HealthCare Alarm Survey showed very low agreement percentages for the statement, "Newer monitoring systems have solved most of the previous problems we experienced with clinical alarms," and low agreement percentages for the statement "Properly setting alarms parameters and alerts is overly complex"(Funk et al., 2014; Petersen & Costanzo, 2017). Interestingly, according to the 2017 UK HealthCare Alarm Survey, monitor watchers were reported as helpful by only 34% of the nurses in the unit without a

dedicated monitor watcher, and by 49% of nurses in the unit that already used a monitor watcher. Moreover, when the UK HealthCare respondents were asked "Has your institution developed or instituted improvements to address alarm safety," respondents expressed a lack of awareness of the development and use of new solutions to improve clinical alarm management. In fact, both questions showed that most nurses were "unsure" about initiates to improve alarm management (Q23 unsure 66% 10th floor; 66% 8th floor; Q24 unsure 70% and 58%, respectively).

Significant Differences in Survey Responses

When the 2017 UK HealthCare Alarm Survey was analyzed for statistically significant differences five questions stood out. In the unit with a monitor watcher, results showed higher agreement percentages when participants were asked whether they agreed or disagreed with the statements, "When a number of devices are used with a patient, it can be confusing to determine which device is in an alarm condition" and "Background noise has interfered with alarm recognition" than the unit without the monitor watcher (p-values 0.015 and 0.046, respectively). Also, the question " have you been educated on alarms" showed a statistically significant difference between the two units with respondents in the 8th floor answering yes at higher percentages than those in the 10th floor (83% and 64% respectively p-value 0.024). Moreover, the question "A resource tool with guidelines to help me troubleshoot and safely adjust parameters to reduce non-actionable and nuisance alarms would be how useful" generated a p - value of 0.001, with 91% of the nurses in the 10th floor sample expressing that a resource tool would be "extremely" or "moderately useful." And when asked if "Clinical policies and procedures regarding alarm management are effectively used in my facility" nurses in the unit with a monitor watcher showed majority agreement (54%) as opposed to nurses in the unit without the monitor watcher which showed low agreement (43%). The 2017 UK HealthCare

Alarm Survey showed statistically significant differences in agreement percentages when the responses were compared between the units surveyed. Although survey findings showed some differences between units at UKMC, recorded alarm events were very different when grouped by unit.

Recorded Alarm Events

During the sample period 32,224 alarms were recorded from 32 different monitors on the 10th floor MICU (n=12077) and 8th floor CVICU (n=20147). When separated into four general categories, the largest number of alarms (49%; n=32224) were generated from the ECG parameters of the bedside monitor. The respiratory parameters generated the second largest section with 30% (n=32224) of the alarms in this category. Pressure alarms accounted for 20% of the total alarms and 1% were temperature and clinical system error alarms. By far, ECG parameters caused the most alarms across both units, with a total of 15,905 ECG alarms recorded. Although, ECG alarms were the most prevalent, this general category of alarms is comprised of up to 26 independent parameters and each floor had a different pattern of alarm frequency.

ECG alarms are generated by several individually set parameters and in total, 6217 alarms were recorded from 26 set parameters in the 10th floor data set. High and low HR alarms were the most predominate, generating 1888 sounds, or about 15.6% of all alarms recorded in that unit (n=12077). "Multiform PVC's" created the second largest group of ECG alarms about 6.48%. "Pair of PVCs" and "Pause" parameters generated 4.51% and 4.40% of all alarms in the unit, followed by ECG (leads off) 3.01% and Arrhythmia, 2.06%. The most prevalent parameter alarms are "HR, Multiform PVC's, Pair of PVC's, and Pause" and as a combined total they

represent 31% of all alarms recorded in the unit. When alarm frequencies are compared to the 8th floor, some differences can be appreciated.

ECG alarms were the most predominate alarm on the 8th floor, producing 9688 (48.1%) of all alarms recorded from the unit. In the ECG category, the "Pause" alarm parameter generated the most alarms, with 11.45% recorded. High and low heart rate parameters produced the second highest number of alarms in this category, with 1587 or 7.88% recorded. "Multiform PVC's" produced the next highest percentage (3.88%), followed by "Pair of PVC's" (2.98%) and "Run of PVC's" (2.64%). The most common alarms in the unit with a monitor watcher are "Pause, HR, Multiform PVC's, Pair of PVC's, and Run of PVC's" and when combined these alarms represented 29% (n=20147) of all alarms in this unit. Although the ECG category generated approximately half of the alarms in both sample sets, the single monitoring parameter that generated the highest independent percentage of alarms was in the respiratory category.

The respiratory monitoring category is made up of nine parameters and when the units are combined these parameters created 9724 alarms. The Spo2 generated the highest number of alarms in the category and the highest percentage of any single parameter in both data sets (15.23% n=32,224)). Respiratory rate alarms (combined as both high and low) produced 7.87% of all alarms in the unit without a monitor watcher and 9.87% of all alarms in the unit with a monitor watcher respectively. Respiratory parameters as a group produced 31.95% of all recorded alarms on the 10th floor and 29.1% of all alarms on the 8th floor. The respiratory category produced about one-third of all alarms and the Spo2 alarm was the most prevalent single alarm parameter overall.

Discussion

The demographics of the studies represented in this analysis vary greatly, and this influences the comparison of their results. The demographics of the 2011 National Alarms survey include an overall response rate of n= 4278, 77% of the sample with greater than 11 years of experience, and RN's making up 33% (n=1414) of the overall sample. In the 2015 Assessment of Clinical Alarms study (Petersen & Costanzo, 2017), the overall response rate was n=26, 19% with greater than 11 years of experience, and 81% of the sample were beside RNs. The 2017 UK HealthCare Alarm Survey included a sample size of n=106, 12% of the sample was greater than 11 years of experience, and 100% of the sample were bedside RN's. The 2011 National Alarms Survey represents a large sample size, yet RNs only comprised 33 % of the overall sample; this is in contrast to the 2015 and 2017 studies where the sample sizes were smaller (n=26 for the 2015 study and n=106 on 2017), yet bedside RNs made up the majority of the samples (81% and 100%, respectively). Additionally, the sample from the 2011 National Alarms Survey was comprised of more experienced providers from multiple practice environments (different hospitals), whereas the samples in the other two studies were largely made up of nurses fewer than 11 years of experience who worked at a single site (Mary Lanning Healthcare and UK HealthCare respectively). Although the same survey was used in all three studies, the differences in sample size and composition may explain the variances found among certain survey responses.

UK HealthCare Alarm Survey Results Compared to Published Studies

Sixteen core questions from the 2011 HTF Alarm Survey were found in two published studies and when these were compared to the results of the 2017 UK HealthCare Alarm Survey the findings are similar, with one notable exception. When participants in the 2017 UK

HealthCare Alarm Survey were asked if they agreed with the statement, "Central alarm management staff 'monitor watchers' responsible for receiving alarm messages and alerting appropriate staff is [sic] helpful," findings showed an overall response of 43% (low agreement), yet published studies report a majority (2011 survey) or high agreement (2015 survey) to this statement. Monitor watchers are reported as helpful by published studies; however, respondents at UK HealthCare believe the use of a monitor watcher is less helpful. Although the findings of the 2017 UK HealthCare Alarm Survey are congruent with those of similar studies, an exception is noted with regard to the perceived helpfulness of monitor watchers.

Survey Results and Alarm events divided by unit

In this practice improvement project, information was separated to determine how responses to the 2017 UK HealthCare Alarms Survey differed in units with (8^{th} floor) or without (10^{th} floor) a dedicated monitor watcher. Sample demographics differed in that a larger percentage of experienced (greater than five years) nurses responded to the survey when administered on the 10^{th} floor. Of those who responded, 49% of the 10^{th} floor nurses had more than five years of experience as opposed to 26% of the nurses on the 8^{th} floor having more than five years of experience. Survey results from the 10^{th} Floor sample set may be influenced by years of experience in nursing. Notwithstanding years of experience, several other factors may influence survey responses such as patient population, and the number of alarm generating devices used in each unit.

The 2017 UK HealthCare Alarms Survey divided results based on unit worked and both units surveyed are considered intensive care; however, several differences between units were found. The patient population, and patient equipment used in each unit varied, as well as the number of recorded alarms. The 10^{th} floor MICU patient population consists primarily of

medical and pulmonary patients requiring ICU level of care whereas the 8th floor CVICU patient population is made up of post-operative cardiac patients, heart and lung transplants, heart failure patients, and those receiving treatment with LVADs and ECMO. Both units use the same equipment to monitor and treat patients, with an exception noted for some patients in the 8th floor where pressure monitoring device use was higher, and LVAD, and ECMO were present. Phillips clinical monitors are used in both units to record ECG, pressure, and respiratory parameters; however, the 8th floor had 20,147 alarms while the 10th floor recorded 12,077. Moreover, the 8th floor has two dedicated monitor watchers who oversee all monitors, while the 10th floor does not have a dedicated person or persons to continuously watch each monitor. With these differences in mind, survey results differed little in terms of the perceived presence and impact of nuisance alarms.

Nuisance alarms are defined in the literature as technically incorrect, repetitive, or clinically irrelevant alarms that distract caregivers from real patient conditions (Cvach et al., 2015; Funk et al., 2014; Graham & Cvach, 2010). A technically incorrect alarm is often difficult to correct, but repetitive and clinically irrelevant alarms can be easily deactivated by monitor users (ECRI Institute, 2014; Graham & Cvach, 2010; Lukasewicz & Andersson Mattox, 2015). Several alarms have been identified as being potentially repetitive and/or clinically irrelevant; these include "Pause, Multiform PVC's, Pair of PVC's, and Run of PVC" (Cvach et al., 2015; Purbaugh, 2014; Sendelbach et al., 2015). Routine review and/or deactivation of these alarms are not standard practice at UK HealthCare and this can explain why nurses in the 2017 UK HealthCare Alarm Survey reported problems with nuisance alarms. Although recorded alarm events were significantly higher in the unit with a monitor watcher than in the unit without one, the rates of potential nuisance alarms were found to be about the same in both units.

Nuisance alarms were identified in both groups as frequent, problematic, and a cause for distrust of monitoring equipment. When compared, the unit with a monitor watcher reported slightly higher agreement scores to "nuisance alarms occur frequently" and "nuisance alarms disrupt care" and slightly lower "distrust" scores than the unit without a monitor watcher; this is most likely because fewer alarms are missed due to a monitor watcher calling nurses to inform them of alarm conditions. Moreover, perceived levels of alarm burden and alarm pollution were high in both units and were not related to the presence of a monitor watcher. Nurses in the unit with a monitor watcher experienced about two alarms from the clinical monitor every minute, compared with about 1.2 alarms in the unit without a watcher. The existence or absence of a dedicated monitor watcher appears to have little influence on nursing perceptions of the presence, and impact of nuisance alarms, nor did the presence of a monitor watcher change the level of alarm burden or alarm pollution reported by nurses. Moreover, the presence of a monitor watcher had very little impact on perceived sensitivity and supposed responsiveness to alarms.

Alarms are designed to alert care providers to changes in patient conditions. The rationale for providing a dedicated monitor watcher is that it will improve alarm response and recognition would be improved; however, this may not always be the case. Responses to questions about perceived alarm sensitivity and alarm response showed no statistically significant differences in this study. It is interesting to note that alarm recognition was reported as being more difficult in the unit with a monitor watcher when compared to the unit without a monitor watcher (p-value 0.0015). The presence of a dedicated monitor watcher does not appear to change perceptions about alarm sensitivity, and or alarm response. Although monitor watchers were already in use in one of the surveyed units during the survey period, participants

were asked directly if they believed cell phones, pagers and or monitor watchers were helpful to improve alarm response.

Alarm integration using wireless communication devices, and/or a dedicated monitor watcher have been proposed as potentially helpful solutions to combat alarm fatigue and improve alarm response, yet nurses seem to find these solutions only moderately helpful. Both units reported majority agreement percentages when asked if cell phones or pagers would be useful. Moreover, in the unit without a monitor watcher, only 34% of the nurses expressed a belief that a monitor watcher would be useful, and only 49% of the nurses in the unit with the monitor watcher present believed it was helpful. In contrast, the use of smart alarms to reduce nuisance alarms was expressed by both units as helpful. Monitor watchers do not appear to be a favored intervention by most nurses in the survey sample to improve alarm response, even when one is already present. Wireless communication devices may show some promise in improving alarm response however, most survey participants believe that smart alarms are the most helpful intervention to improve alarm response. Although, smart alarms seem to offer a future solution, survey respondents report that current efforts to improve alarm safety are somewhat lacking.

The Joint Commission lists "using alarms safely" as National Patient Safety Goal #6, and every hospital that desires accreditation must make efforts to meet that goal. Yet, with so many alarms in use in the average hospital it can be difficult to develop and disseminate meaningful policies, education, and practice changes to staff members in a timely fashion. Nurses at UK HealthCare confirm this reality in their survey answers, irrespective of the unit they worked in, less than half of all participants agreed with the statement, "Clinical policies and procedures regarding alarm management are effectively used in my facility." Moreover, no differences were found between the units with regard to the availability of resources and recommended practices.

Yet, in contrast, there is a statistically significant (p-value 0.019) difference between the units in terms of education.

Nurses in the unit with a monitor watcher expressed higher education percentages 83%, monitor watcher 64%, no monitor watcher, and this may be explained by differences in orientation length and focus. Orientation schedules and required education are different in each unit and this impacted respondents' expressed level of education. A standardized approach to monitor education and alarm management strategies would be useful to even out education gaps. Overall, it appears that most nurses are unaware or are unsure of the improvements in the clinical policies, procedures, and resources that are available to them in their respective units and this does not seem to be directly related to the presence of monitor watchers. Unfortunately, because resources and policies are viewed as lacking, some nurses attempt to reduce nuisance alarms with potentially unsafe behaviors.

Workarounds are common in nursing units, and when alarm burden and alarm pollution rates are high, some nurses may engage in potentially unsafe behaviors to reduce false alarms. The oversight of a dedicated monitor watcher should reduce the occurrence of potentially unsafe workarounds because providers are held accountable when alarms are deactivated, yet nurses in both units reported that they have found A-line and Pulse oximetry alarms turned off at least once a week or more. Moreover, 77% of the nurses surveyed reported believing that the forehead is an acceptable place to monitor pulse oximetry, even though the hospital does not provide forehead probes for that use. Even though this placement may produce a stable waveform (fewer nuisance alarms), the reading is highly unreliable and often inaccurate. The 2017 UK HealthCare Alarm Survey results show that irrespective of the attendance of a monitor watcher, nurses engage in potentially unsafe workarounds. The addition of a dedicated monitor

watcher in the CVICU is a change from the traditional intensive care culture for this workplace, yet when survey responses from the 2017 UK HealthCare Alarms Survey were examined very few differences in terms of alarm perspectives and practices were found.

Limitations

This study has several limitations, including small sample size and the inability to limit confounding variables such as technically inaccurate alarms (artifact versus real alarms) and nurse or monitor watcher interactions with the clinical monitor. The link to the survey was sent to approximately 210 nurses. The response rate was 51% which yielded a sample size of 106. The survey response rate was good but this sample only represents two out of eight adult critical care units in the hospital.

Only a small percentage of UK nurses and alarm events are represented in this study. Other confounding variables such a patient movement may produce alarms that were recorded as technically correct, yet they are nuisance alarms. It is beyond the scope of this project to review each alarm event for accuracy therefore the true number of all types of nuisance alarms could not be recorded in this study. Moreover, certain nursing and monitor watcher practices may have occurred during the data collection period that impacted the alarm event data and these factors were not controlled.

As part of routine care activities, some bedside nurses and monitor watchers customize alarm settings, and this information was beyond the scope of this project to control or record. Individual nurses and or monitor watchers are empowered to change default alarm settings if customization is desired. This practice is not consistent and varies greatly based on nurse or monitor watcher preference and clinical judgement. Customization of alarms may have occurred during alarm event collection, and this would skew event data. Although this study has several

limitations the findings do point out areas where practice changes and future research are warranted.

Recommendations for Practice Changes

The results of this study suggest several recommendations for practice changes at UK HealthCare including reducing repetitive and clinically irrelevant alarms and updating staff education. Nuisance alarms made up almost a third of all alarms in each unit, and the current practices of bedside providers and monitor watchers have not effectively mitigated this problem. A policy that allows for the routine deactivation of repetitive alarms such as Pause, Multiform PVC's, Pair of PVC's, and Run of PVC is recommended. Additionally, this policy can require adjustment to default heart rate settings in the event of stable bradycardia as well as disabling Irregular HR and A-Fib alarms in the setting of known A-Fib (Cosper et al., 2017). Even though this policy would provide institutional support to the effort to reduce nuisance alarms, staff education about policy changes and unsafe alarm management practices is required.

As reported in this study nurses at UK HealthCare are unaware of administrative interventions to alleviate alarm fatigue and improve alarm safety; this indicates a need to update staff education. Nursing turnover and the rapid growth of new staff members can explain lapses in education like those noted in the survey results, yet interventions designed to improve bedside provider knowledge of alarm management practices are crucial to ensure safe alarm use (Brantley et al., 2016; ECRI Institute, 2014). Educational efforts can include inservices that discuss the impact of nuisance alarms on patient safety, and detail new policies enacted regarding alarm customization. Once these interventions are complete, future research is recommended to evaluate and explore other causes for alarm fatigue.

Recommendations for Future Studies

Several recommendations for future studies were discovered during this project. Alarm fatigue is a complex and multifactorial problem and as such it lends itself to a broad range of research endeavors. Alarm fatigue is often difficult to define and measure; focus group research with bedside nurses may reveal insights that can be used to form a deeper understanding of how factors like experience, staffing ratios, and nursing workload influence alarm management practices. Also, it is recommended that more information be obtained about the impact of monitor watchers on safety outcomes such as unrecognized patient decline, missed alarms, and or alarm related sentinel events. While these proposed studies may provide insights into some of the human factors related to alarms, research is also needed to better understand the mechanical aspects of nuisance alarms.

Equipment, both hardware and software, can influence the types and frequency of nuisance alarms and research is required to better understand these phenomena. As noted in this study, the monitoring parameter with the most recorded alarms is SpO2, this finding is consistent with other published studies which describe high rates of clinically irrelevant and technically incorrect SpO2 alarms (Graham & Cvach, 2010; Phillips & Barnsteiner, 2005; Varpio et al., 2012). Further research is recommended at UK HealthCare that targets this parameter to determine the rate of real versus technically incorrect readings. Once an understanding of the rates of nuisance pulse oximetry alarms is confirmed, studies that explore the use of approved forehead probes and/or low perfusion pulse oximetry probes could be conducted to determine if the use of such products can reduce nuisance SpO2 alarms.

Conclusion

In conclusion, this project has examined the perspectives and practices of nurses regarding clinical monitor alarms at the University of Kentucky Medical Center. These findings have been compared to published studies and analyzed in the context of the presence or absence of a monitor watcher. Additionally, the number and types of alarms recorded in two critical care units at UKHC have been established. The research objectives proposed in this study have been met. Aside from the meeting these objectives, this project has also served as an evaluation of the introduction of a monitor watcher into the critical care environment.

Nurses at UK HealthCare report nuisance alarms to be a problem and the addition of a monitor watcher in the intensive care environment did not appear to reduce the number of repetitive and clinically irrelevant alarms found in this study. The rates of nuisance ECG alarms appear to be equal regardless of the presence of a monitor watcher. High levels of perceived alarm burden and alarm pollution were reported in equal measure in both units. These findings identify a need to reform how nuisance alarms are handled at UK HealthCare. Deactivation of repetitive and clinically irrelevant alarms is a proposed solution that is suggested to reduce the occurrence of some nuisance alarms. Interventions such as routine deactivation of repetitive and clinically irrelevant alarms many result in a lessening of the factors that contribute to the development of alarm fatigue. While a lessening of nuisance alarms is warranted, gaps in nursing education related to alarm management were also identified.

This project has revealed gaps in perceived education for nurses in the surveyed units. The lack of consistent education was identified by the survey instrument and by the potentially unsafe workarounds that were reported by nurses. Reported level of education was different between the units with nurses in the CVICU reporting higher agreement scores when compared

to those in the MICU. Also nurses in the MICU expressed a desire for a guideline to help them troubleshoot alarm conditions. A standardized approach to alarm management education will close this gap and hopefully reduce unsafe workarounds in both units.

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Appendix A

Table 1.

Demographics of survey respondents: Years of experience as a nurse.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	New Graduate less than 6 months experience	11	10.2	10.3	10.3
	6 months to 1 year	6	5.6	5.6	15.9
	1 year to 3 years	29	26.9	27.1	43.0
	3 years to 5 years	22	20.4	20.6	63.6
	5 years to 10 years	26	24.1	24.3	87.9
	10 years to 20 years	7	6.5	6.5	94.4
	Greater than 20 years	6	5.6	5.6	100.0
	Total	107	99.1	100.0	
Missing	System	1	.9		
Total		108	100.0		

Table 2.

Demographics of survey respondents: Unit worked in and years of experience.

		How long have you been a registered nurse?							
		New Graduate less than 6 months experience	6 months to 1 year	1 year to 3 years	3 years to 5 years	5 years to 10 years	10 years to 20 years	Greater than 20 years	Total
Which ICU area do you work in?	10th Floor MICU	5	0	12	7	14	3	6	47
	8th Floor CVICU	6	6	17	14	11	4	0	58
Total		11	6	29	21	25	7	6	105

Table 3. UK Healthcare survey results compared to published studies.
Percentages are expressed as percentage of those responding "Strongly agree or Agree" with the following questions.

Question	2011 National Alarms Survey (Funk et al., 2014) (n=4278)	2015 Assessment of Clinical Alarms (Petersen & Costanzo, 2017) (n=26)	2017 UK Healthcare Alarms Survey (n=106)
Nuisance alarms occur frequently	76%	88%	94%*
Nuisance alarms disrupt patient care:	71%	96%	91%
Nuisance alarms reduce trust in alarms and cause care givers to inappropriately turn alarms off at times other than during setup or procedures:	78%	100%	95%
Properly setting alarm parameters and alerts is overly complex in existing devices	21%	42%	30%
The alarms used on my floor/area of the hospital are adequate to alert staff of potential or actual changes in a patient's condition:	72%	73%	73%
There have been frequent instances where alarms could not be heard and were missed:	29%	35%	54%
Clinical staff is sensitive to alarms and responds quickly:	66%	54%	57%
Newer monitoring systems (e.g., less than three years old) have solved most of the previous problems we experienced with clinical alarms:	33%	15%	12%

Clinical policies and procedures regarding alarm management are effectively used in my facility:	55%	58%	49%
When a number of devices are used with a patient, it can be confusing to determine which device is in an alarm condition:	51%	54%	71%
Background noise has interfered with alarm recognition:	42%	47%	62%
Central alarm management staff ("monitor watchers") responsible for receiving alarm messages and alerting appropriate staff is helpful:	53%	84%	43%
Alarm integration and communication systems using pagers, cell phones, or other wireless devices are useful for improving alarm management and response:	56%	81%	57%
Smart alarms (e.g., where multiple parameters, rate of change of parameters, and signal quality, are automatically assessed in their entirety) would be effective to use for reducing false alarms:	78%	80%	78%
Smart alarms (e.g., where multiple parameters, rate of change of parameters, and signal quality, are automatically assessed in their entirety) would be effective to use for improving clinical response to important patient alarms:	78%	89%	82%
Is there a requirement in your institution/unit to document that the alarms are set and are appropriate for each patient?	71%	35%	90%

Table 4.
Perspectives and practices of nurses using clinical alarm systems in a unit without monitor watcher versus unit with monitor watcher at UKHC.
The following table lists the percentages of respondents, divided by unit, who "Strongly Agree or Agree" with the following statements. The last column shows the p-value to express statistical differences in responses.

Question*	2017 UK Healthcare Alarms Survey (n=106)	2017 UK Healthcare Alarms Survey 10th Floor Unmonitored (n=47)	2017 UK Healthcare Alarms Survey 8th Floor Monitored (n=59)	p-value
Q3. Nuisance alarms occur frequently	94%	91%	97%	0.687
Q4. Nuisance alarms disrupt patient care:	91%	87%	93%	0.051
Q5. Nuisance alarms reduce trust in alarms and cause care givers to inappropriately turn alarms off at times other than during setup or procedures:	95%	100%	92%	0.457
Q6. Properly setting alarm parameters and alerts is overly complex in existing devices	30%	32%	20%	0.262
Q7. Newer monitoring systems (e.g., less than three years old) have solved most of the previous problems we experienced with clinical alarms:	12%	17%	8%	0.097

Q8. The alarms used on my floor/area of the hospital are adequate to alert staff of potential or actual changes in a patient's condition:	73%	79%	68%	0.986
Q9. There have been frequent instances where alarms could not be heard and were missed:	54%	59%	49%	0.226
Q10. Clinical staff is sensitive to alarms and responds quickly:	57%	60%	54%	0.774
Q11. When a number of devices are used with a patient, it can be confusing to determine which device is in an alarm condition:	71%	66%	75%	0.015
Q12. Background noise has interfered with alarm recognition:	62%	53%	69%	0.046
Q14. Alarm integration and communication systems using pagers, cell phones, or other wireless devices are useful for improving alarm management and response:	57%	60%	56%	0.377
Q16. Central alarm management staff ("monitor watchers") responsible for receiving alarm messages and alerting appropriate staff is helpful:	43%	34%	49%	0.962

Q18. Smart alarms (e.g., where multiple parameters, rate of change of parameters, and signal quality, are automatically assessed in their entirety) would be effective to use for reducing false alarms:	78%	83%	74%	0.226
Q19. Smart alarms (e.g., where multiple parameters, rate of change of parameters, and signal quality, are automatically assessed in their entirety) would be effective to use for improving clinical response to important patient alarms:	82%	81%	83%	0.941
Q21. Is there a requirement in your institution/unit to document that the alarms are set and are appropriate for each patient?	90%	87%	92%	0.284
Q22. Clinical policies and procedures regarding alarm management are effectively used in my facility:	49%	43%	54%	0.015
Q26. The Joint Commission's National Patient Safety Goal on Alarm Management that became effective in 2014 has reduced adverse patient events:	27%	23%	28%	0.800
Q27. When considering the Phillips bedside monitor at UK	80%	77%	83%	0.415

Healthcare I experience a high level of alarm burden				
Q28. At UK Healthcare I experience a high level of alarm pollution generated from the bedside monitor.	90%	87%	92%	0.602
Q29. At UK Healthcare I feel empowered to safely adjust alarms to prevent alarm fatigue	80%	77%	83%	0.191
Q31. UK Healthcare has resources and recommended practices available to help me safely reduce nuisance alarms	25%	28%	22%	0.743
Q32. A resource tool with guidelines to help me troubleshoot and safely adjust parameters to reduce non-actionable and nuisance alarms would be how useful	77%	91%	66%	0.001
Q33. Adjusting default alarm settings and parameters to each patient's condition is an important part of my job	90%	89%	90%	0.876

* Level of agreement is rated as: Very high agreement >90%, High agreement 66%-89%, Majority agree 50-65%, Low agreement 33-49%, and Very low <33%

Table 5. Alarm events recorded from 10th Floor Alarms n=12077

ECG			Pressure		
Alarm Type	**Frequency**	**Percentage**	**Alarm Type**	**Frequency**	**Percentage**
AFIB	27	0.22	**ABP**	14	0.12
Arrhy	249	2.06	**ABPm**	636	5.27
Asystole	24	0.2	**ABPs**	433	3.59
ECG	364	3.01	**NBP**	141	1.17
HR	1888	15.63	**NBPm**	399	3.3
Irregular	182	1.51	**NBPs**	228	1.89
LA	1	0.01		**1851**	15.33
LL	13	0.11			
Missed	171	1.42			
Multiform	782	6.48			
Non	57	0.47			
PVCs	191	1.58			
Pacer	39	0.32			
Pair	545	4.51			
Pause	531	4.40			
QT	68	0.56			
RA	16	0.13			
R on T	12	0.1			
Run	71	0.59			
ST	644	5.33			
STE	186	1.54			
SVT	4	0.03			
VTach	16	0.13			
Vent	36	0.3			
xBrady	42	0.35			
xTachy	58	0.48			
	6217	51.5			

Respiratory		
Alarm Type	**Frequency**	**Percentage**
Apnea	81	0.67
Desat	129	1.07
RR	951	7.87
Pulse	108	0.89
Resp	91	0.75
SpO2	1885	15.61
awRR	209	1.73
etCO2	404	3.35
imCO2	1	0.01
	3859	31.95

Temp	145	1.2
User	3	0.02
Check	2	0.02
	150	1.24

Table 6. Alarm events recorded from 8th floor CVICU. n=20147

ECG			Pressure		
Alarm Type	**Frequency**	**Percentage**	**Alarm Type**	**Frequency**	**Percentage**
AFIB	171	0.85	**ABP**	45	0.22
Arrhy	310	1.54	**ABPm**	1689	8.38
Asystole	5	0.02	**ABPs**	1349	6.70
Brady	4	0.02	**ARTm**	22	0.11
ECG	473	2.35	**ARTs**	5	0.02
Extreme	10	0.05	**NBP**	215	1.07
HR	1587	7.88	**NBPm**	415	2.06
Irregular	270	1.34	**NBPs**	252	1.25
			CPP	1	0
Missed	155	0.77	**CVPm**	338	1.68
Multiform	781	3.88	**PAP**	7	0.03
Non	329	1.63	**PAPd**	130	0.65
PVCs	414	2.05		**4468**	
Pacer	153	0.76			
Pair	601	2.98			
Pause	2306	11.45			
QT	78	0.39			
R	30	0.15			
Run	435	2.64			
ST	532	2.65			
STE	224	1.11			
SVT	41	0.20			
VTach	206	1.02			
Vent	375	1.86			
xBrady	10	0.05			
xTachy	188	0.93			
	9688				

Resp		
Alarm Type	**Frequency**	**Percentage**
Apnea	112	0.56
Desat	237	1.18
Pulse	224	1.11
RR	1989	9.87
Resp	143	0.71
SpO2	3022	15.00
etCO2	138	0.68
	5865	

Temp	77	0.38
User	43	0.21
Check	6	0.03
	126	

Appendix B

2017 UK HealthCare Alarm Survey

Start of Block: Default Question Block

Thank you for participating in the 2017 UK HealthCare Alarms survey. This survey is like the HTF national surveys completed by 1,327 individuals in 2006 and by 4,278 in 2011 to determine changes in the perception of clinical alarm-related issues, event occurrence, improvement measures, and the priority for action.

This survey has two sections: A. Work-related demographics and B. Alarm-related information, with a total of 37 multiple choice and free-text questions. Please base your answers to questions on your own experience. It should take you no more than 15 minutes to complete the survey.

Participation in this study is completely voluntary. This anonymous Qualtrics survey does not track participant information or IP address. No identifiable information will be obtained.

You should not expect any direct benefit as a result of participating in this research, and you will not be compensated for your participation. The results of this survey will help to inform the healthcare community about the current status of issues related to clinical alarms and perhaps provide ideas for targeted areas for improvement.

Q1 **Which ICU area do you work in ?**

O 10th Floor MICU (1)

O 8th Floor CVICU (2)

2 **How long have you been a registered nurse ?**

- O New Graduate less than 6 months experience (1)
- O 6 months to 1 year (2)
- O 1 year to 3 years (3)
- O 3 years to 5 years (4)
- O 5 years to 10 years (5)
- O 10 years to 20 years (6)
- O Greater than 20 years (7)

Q3 **Nuisance alarms include both false and non-actionable alarms. False alarms occur when there is no valid triggering event, whereas non-actionable alarms correctly sound, but for an event for which no clinical intervention or action would be taken. Please answer the following questions about nuisance alarms. * Nuisance alarms occur frequently:**

- O Strongly agree (1)
- O Agree (2)
- O Neither agree nor disagree (3)
- O Disagree (4)
- O Strongly disagree (5)

Q4 **Nuisance alarms disrupt patient care:**

- O Strongly agree (1)
- O Agree (2)
- O Neither agree nor disagree (3)
- O Disagree (4)
- O Strongly disagree (5)

Q5 **Nuisance alarms reduce trust in alarms and cause care givers to inappropriately turn alarms off at times other than during setup or procedures:**

- O Strongly agree (1)
- O Agree (2)
- O Neither agree nor disagree (3)
- O Disagree (4)
- O Strongly disagree (5)

Q6 **Properly setting alarm parameters and alerts is overly complex in existing devices**

- O Strongly agree (1)
- O Agree (2)
- O Neither agree nor disagree (3)
- O Disagree (4)
- O Strongly disagree (5)

Q7 **Newer monitoring systems (e.g., less than three years old) have solved most of the previous problems we experienced with clinical alarms:**

- O Strongly agree (1)
- O Agree (2)
- O Neither agree nor disagree (3)
- O Disagree (4)
- O Strongly disagree (5)

Q8 **The alarms used on my floor/area of the hospital are adequate to alert staff of potential or actual changes in a patient's condition:**

- O Strongly agree (1)
- O Agree (2)
- O Neither agree nor disagree (3)
- O Disagree (4)
- O Strongly disagree (5)

Q9 **There have been frequent instances where alarms could not be heard and were missed:**

- O Strongly agree (1)
- O Agree (2)
- O Neither agree nor disagree (3)
- O Disagree (4)
- O Strongly disagree (5)

Q10 **Clinical staff is sensitive to alarms and responds quickly:**

- O Strongly agree (1)
- O Agree (2)
- O Neither agree nor disagree (3)
- O Disagree (4)
- O Strongly disagree (5)

Q11 **When a number of devices are used with a patient, it can be confusing to determine which device is in an alarm condition:**

- O Strongly agree (1)
- O Agree (2)
- O Neither agree nor disagree (3)
- O Disagree (4)
- O Strongly disagree (5)

Q12 **Background noise has interfered with alarm recognition:**

- O Strongly agree (1)
- O Agree (2)
- O Neither agree nor disagree (3)
- O Disagree (4)
- O Strongly disagree (5)

Q13 **Does your hospital use alarm notification systems such as pagers, cell phones, or other wireless devices to communicate alarm conditions?**

- O Strongly agree (1)
- O Agree (2)
- O Neither agree nor disagree (3)
- O Disagree (4)
- O Strongly disagree (5)

Q14 **Alarm integration and communication systems using pagers, cell phones, or other wireless devices are useful for improving alarm management and response:**

- O Strongly agree (1)
- O Agree (2)
- O Neither agree nor disagree (3)
- O Disagree (4)
- O Strongly disagree (5)

Q15 **Does your institution use "monitor watchers" in a central viewing area to observe and communicate alarm conditions to caregivers?**

- O Yes (1)
- O Unsure (2)
- O No (3)

Q16 **Central alarm management staff ("monitor watchers") responsible for receiving alarm messages and alerting appropriate staff is helpful:**

- O Strongly agree (1)
- O Agree (2)
- O Neither agree nor disagree (3)
- O Disagree (4)
- O Strongly disagree (5)

Q17 **Does your institution use systems that employ smart alarms (e.g., where multiple parameters, rate of change of parameters, and signal quality, are automatically assessed in their entirety)?**

- O Yes (1)
- O Unsure (2)
- O No (3)

Q18 **Smart alarms (e.g., where multiple parameters, rate of change of parameters, and signal quality, are automatically assessed in their entirety) would be effective to use for reducing false alarms:**

- O Strongly agree (1)
- O Agree (2)
- O Neither agree nor disagree (3)
- O Disagree (4)
- O Strongly disagree (5)

Q19 **Smart alarms (e.g., where multiple parameters, rate of change of parameters, and signal quality, are automatically assessed in their entirety) would be effective to use for improving clinical response to important patient alarms:**

- O Strongly agree (1)
- O Agree (2)
- O Neither agree nor disagree (3)
- O Disagree (4)
- O Strongly disagree (5)

Q20 **If you are responsible for clinical alarms, have you been educated on the purpose and proper operation of alarm systems?**

- O Yes (1)
- O Unsure (2)
- O No (3)

Q21 **Is there a requirement in your institution/unit to document that the alarms are set and are appropriate for each patient?**

- O Yes (1)
- O Unsure (2)
- O No (3)

Q22 **Clinical policies and procedures regarding alarm management are effectively used in my facility:**

- O Strongly agree (1)
- O Agree (2)
- O Neither agree nor disagree (3)
- O Disagree (4)
- O Strongly disagree (5)

Q23 **Has your institution developed clinical alarm improvement initiatives over the past two years (e.g. policies and procedures, education, special projects, new technology)?**

O Yes (1)

O Unsure (2)

O No (3)

Q24 **Has your institution instituted new technological solutions to improve clinical alarm safety?**

O Yes (1)

O Unsure (2)

O No (3)

Q25 **Has your institution experienced adverse patient events in the last two years related to clinical alarm problems**

O Yes (1)

O Unsure (2)

O No (3)

Q26 **The Joint Commission's National Patient Safety Goal on Alarm Management that became effective in 2014 has reduced adverse patient events:**

- O Strongly agree (1)
- O Agree (2)
- O Neither agree nor disagree (3)
- O Disagree (4)
- O Strongly disagree (5)

Q27 **Alarm burden refers to the amount of time and skills needed to safely set, troubleshoot, and respond to alarms in a way that makes each alarm clinically meaningful.**
When considering the Phillips bedside monitor at UK Healthcare I experience a high level of alarm burden

- O Strongly agree (1)
- O Agree (2)
- O Neither agree nor disagree (3)
- O Disagree (4)
- O Strongly disagree (5)

Q28 **Alarm pollution occurs when there is a high number of false, non-actionable and nuisance readings from a medical device. For the purposes of this survey, please only consider alarms from the clinical monitor**

(Phillips bedside monitor).
At UK Healthcare I experience a high level of alarm pollution generated from the bedside monitor.

O Strongly agree (1)

O Agree (2)

O Neither agree nor disagree (3)

O Disagree (4)

O Strongly disagree (5)

Q29 **At UK Healthcare I feel empowered to safely adjust alarms to prevent alarm fatigue.**

O Strongly agree (1)

O Agree (2)

O Neither agree nor disagree (3)

O Disagree (4)

O Strongly disagree (5)

Q30 **Which of the following nuisance alarms do you consider the most difficult to solve? Rank by difficulty.**
_____ Leads off (1)
_____ Pulse oximetry not working (2)
_____ False V-Tach/Asystole (3)
_____ Repetitive or Non actionable alarms (4)

Q31 **UK Healthcare has resources and recommended practices available to help me safely reduce nuisance alarms.**

- O Strongly agree (1)
- O Agree (2)
- O Neither agree nor disagree (3)
- O Disagree (4)
- O Strongly disagree (5)

Q32 **A resource tool with guidelines to help me troubleshoot and safely adjust parameters to reduce non-actionable and nuisance alarms would be how useful ?**

- O Extremely useful (1)
- O Moderately useful (2)
- O Slightly useful (3)
- O Neither useful nor useless (4)
- O Slightly useless (5)

Q33 **Adjusting default alarm settings and parameters to each patient's condition is an important part of my job?**

- O Strongly agree (1)
- O Agree (2)
- O Neither agree nor disagree (3)
- O Disagree (4)
- O Strongly disagree (5)

Q34 **At UK Healthcare the following sites are used to monitor pulse oximetry. Check all that apply.**

- ☐ Finger (1)
- ☐ Toes (2)
- ☐ Forehead (3)
- ☐ Nose (4)
- ☐ Ear (5)

Q35 **In the last 30 days I have experienced situations where an A-line alarm is turned off to prevent it from alarming with inaccurate readings.**

- O Daily (1)
- O 4-6 times a week (2)
- O 2-3 times a week (3)
- O Once a week (4)
- O Never (5)

Q36 **I have experienced situations where the pulse oximetry alarm has been turned off to prevent it from alarming with inaccurate readings.**

- O Daily (1)
- O 4-6 times a week (2)
- O 2-3 times a week (3)
- O Once a week (4)
- O Never (5)

End of Block: Default Question Block