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ABSTRACT

Objectives: To determine critical care nurses' knowledge of alarm fatigue and practices toward alarms in critical care settings. Alarm fatigue (AF) refers to the desensitisation of healthcare practitioners to alarms caused by sensory overload through over exposure to an excessive number of alarms.

Research Methodology/Design: A cross-sectional survey using an adaptation of The Health Technology Foundation Clinical Alarms Survey.

Setting: A sample of 250 critical care nurses from 10 departments across six hospitals in Ireland.

Results: Achieved response rate was 66.4%(n=166). All hospital sites reported patient adverse events related to clinical alarms. The majority of nurses 52%(n=86) did not know, or were unsure, how to prevent alarm fatigue. Whilst 90%(n=148) agreed that non-actionable alarms occurred frequently, disrupted patient care 90.6%(n=145), and reduced trust in alarms prompting nurses to sometimes disable alarms 80.5%(n=132). Nurses claiming to know how to prevent alarm fatigue stated they customised patient alarm parameters frequently (p= 0.037). Frequent false alarms causing reduced attention or response to alarms ranked the number one obstacle to effective alarm management; this was followed by inadequate staff to respond to alarms. Only 31%(n=50) believed that alarm management policies and procedures were used effectively. Less than half 48%(n=77) believe alarm management practices incorporated best available evidence to prevent adverse events.

Conclusion: Alarm fatigue has the potential for serious consequences for patient safety and answering numerous alarms drains nursing resources.

Key Words: Alarm Fatigue, Alarm Management, Clinical Alarms, Patient Safety
IMPLICATIONS FOR CLINICAL PRACTICE

- Alarm fatigue has the potential for serious consequences for patient safety with the worst-case scenario resulting in death or serious patient harm
- Non-actionable alarms occur frequently and disrupt patient care
- Research regarding alarm fatigue is in its infancy
- Measuring alarm fatigue among critical care nurses should be a priority for nurse researchers
INTRODUCTION

Medical devices rely on auditory alarms to alert clinicians to deviations from a predetermined normal status in either equipment or patient, safeguarding against harm (American College of Clinical Engineering Healthcare Technology Foundation [ACCE HTF], 2007). However, healthcare technology advances have resulted in the exponential growth of medical device auditory alarm sounds (Borowski et al., 2011). This is despite evidence highlighting that the human ear has difficulty distinguishing more than 6 different sounds (Patterson, 1982).

Nurses have become overwhelmed by the sheer volume of alarms leading to alarm apathy (Sendelbach and Funk, 2013). The number of alarms has exploded from as many as 100 to 771 alarms per monitored bed per day (Graham and Cvach, 2010) and the majority of alarms are estimated to be false or in-actionable (Siebig et al., 2010). The technology that has been designed to save lives has therefore been accused of becoming the ‘problem’ (Emergency Care Research Institute (ECRI), 2014). This viewpoint is supported by records associating clinical alarms with patient deaths. For instance, Cvach (2012) reviewed the Manufacturer and User Facility Device Experience (MAUDE) database kept by the FDA for four months in 2010 finding 73 deaths related to alarms, of which 33 were attributed to physiological monitors. In addition, a search of the MAUDE database discovered 216 deaths related to physiologic monitor alarms, and while alarms sounded in 73 cases, they were not attended due to being silenced, volumes lowered or other reasons (Keller, 2012). Moreover, it is claimed that the actual death rate related to clinical alarms may
be ten times higher than declared (The Association for the Advancement of Medical Instrumentation [AAMI], 2011). It is therefore not surprising that up until 2016 the US-based independent patient safety research organisation (ECRI) has positioned alarm hazards as number one or two of the annual Top 10 Health Technology Hazards since the list was devised in 2007. In addition, alarm management was designated a National Patient Safety Goal for 2014, 2015 and 2016.

Researchers have only recently been exploring the phenomenon of alarm fatigue (Alsaad et al., 2017; Bonafide et al., 2014; Cho et al., 2016; Deb and Claudio, 2015; Drew et al, 2014; Funk et al., 2016; Gazarian et al., 2015; Honan et al., 2015; Joshi et al., 2017; Varpio et al., 2012), and most of this research emanates from North America. This could in part be explained by the different nurse-patient ratios between the US and elsewhere and the practice of nursing patients in single rooms rendering American nurses more reliant on alarms to monitor their patients.

METHODOLOGY

Research design

This study aimed to determine critical care nurses’ knowledge of alarm fatigue and their attitudes, perceptions and practices towards clinical alarms. A descriptive cross sectional design was used to survey critical care nurses working in 10 various departments throughout six different hospitals in the west of Ireland.
Instrument

The Health Technology Foundation (HFT) 2011 Clinical Alarms Survey (CAS) (Funk et al., 2014) was used in the study. No details of this instrument’s content validity are documented in the published literature; however numerous professional organisations provided assistance with the instrument’s design, and it has been used to survey healthcare professionals throughout the US in 2005-2006, 2011, and 2016 (Korniewicz et al., 2008; Funk et al., 2014; Clark, 2016). The instrument has also been used in several other studies to evaluate nurses’ perception of alarms (Baird, 2015; Cho et al., 2016; Deb and Claudio, 2015; Sowen et al., 2015; Petersen and Costanzo, 2017; Turmell et al., 2017).

Permission was granted by the HFT to use the instrument and to make adaptations. The adapted survey contained four main sections with 42 items including eight demographic questions. Three preliminary knowledge questions were added below the demographic section using a closed-ended yes/no/unsure response format to query: A) familiarity with the term alarm fatigue, B) cause of alarm fatigue and C), prevention of alarm fatigue.

Section three asked respondents to rate their level of agreement with 19 statements related to clinical alarms using a 5 point Likert scale from strongly agree to strongly disagree. Three closed-ended questions with a yes/no/unsure format from the 2011 CAS were included. In section four, nurses were asked to rate nine issues which inhibit effective alarm management using a nine point scale from 1 (most important) to 9 (least important).
The CAS survey was further adapted to suit the Irish demographic by omitting questions 21, 23, and 30 as they pertained to alarm communication systems and central monitor watchers which are not utilised throughout the study settings. Question 13 was omitted as it referred to the Joint Commission which is not the accreditation body used in public hospitals in Ireland. An alternative question which generated similar information was devised “Alarm management practices within my area incorporate best available evidence to prevent patient adverse events”. Finally, an additional question (No. 19) was added: “I always customise patient alarm parameters at the beginning of a shift and adjust accordingly throughout the day”. This question was based on an extensive review of the literature to gather information on the extent to which the practice of customising alarms to patients occurs. A reduction of 43% in nuisance alarms through customising threshold alarms has been reported (Graham and Cvach, 2010). Individualising alarm parameters as opposed to using default settings is advocated as a method for reducing alarm load and hence the potential for alarm fatigue (AACN, 2013; AAMI, 2011; Brantley et al., 2016 Gross et al., 2011; Phillips, 2006).

The time frame for the question which queried adverse events related to clinical alarms was changed from ‘two’ to ‘five’ years to capture whether nurses were knowledgeable about the two confirmed alarm related deaths in 2012 and 2014 at Centre A. This change was deemed important as the researchers wished to ascertain if staff were aware of these adverse events. Improved and open communication is necessary in healthcare related critical incidents associated with alarms (David and Clark, 2013). Furthermore, the national safety incident
management policy for the public health service in Ireland stipulates that critical incident findings must be disseminated to leverage learning from safety incidents.

The term ‘institution’ was replaced with ‘Hospital’ and the word ‘problems’ omitted in two questions, and the term ‘institution’ was replaced by ‘area’ in the question pertaining to clinical alarm improvement initiatives to garner information regarding critical care areas only. In addition, questions including the term ‘nuisance alarms’ were altered to ‘non-actionable/nuisance alarms’ to assist with question clarity and to make explicit which alarms were being referenced. Finally, one open ended question invited any comments from respondents.

The adapted HFT instrument was pretested among nine critical care nurses and issues with the layout of the nine point scale was highlighted, and subsequently reformatted.

A reliability analysis of the adapted instrument conducted using the statistical package for the social sciences (SPSS) generated a Cronbach’s Alpha of 0.73 demonstrating internal consistency for the final instrument utilised in the study.

**Ethical Considerations**

Ethical approval was granted for all hospital sites between December 3\textsuperscript{rd}, 2015 and January 16\textsuperscript{th}, 2016. A cover letter accompanied the survey explaining that participation was voluntary and that the survey was anonymous.

**Setting**
Five hospitals included in the study were Model 3 hospitals which have intensive care facilities on site and emergency departments open 24/7. All were teaching hospitals with university affiliation (Table 1). One hospital had Model 4 status as it was the regional tertiary referral centre. Site A was the only hospital with a Post Anaesthetic Care Unit (PACU). Nurses at this hospital rotated from Intensive Care Unit (ICU), High Dependency Unit, (HDU) to PACU, therefore including PACU was deemed appropriate. The small number of PACU nurses 2.87% (n=8) was not anticipated to affect the data.

**Participant Selection**

Non-probability consecutive convenience sampling was used. The accessible sample was identified as all registered nurses working in critical care areas inclusive of ICU, HDU, and PACU within the 6 hospitals of level 3 and greater along the Western Seaboard of Ireland (N=278). Excluding 12 nurses from the single private hospital in the study, the total population included 266 nurses representing 19.25 % of the total public sector critical care staff across Ireland (Health Service Executive [HSE] 2014). Non-clinical nursing staff were excluded on the basis that the study wished to capture those individuals who are over-exposed to clinical alarms and subsequently suffering from alarm fatigue. Nurses on long term leave and sick and maternity leave were also excluded. Following exclusion criteria, the sampling population was reduced by 10% to 250 nurses.

**Data collection**
The two page paper instrument, with cover letter attached by staple, was distributed by the first author in person to each site. Data was collected over a one month period from mid-February to mid-March 2016. A tray of surveys was positioned beside the survey collection box. Respondents were invited to take a survey, and return the completed survey to the collection box. Colour A3 posters advertising the study were hung in the staff rooms and a champion was recruited at each site to promote the study.

Data Analysis

The IBM SPSS version 22 was used to analyse the data. Descriptive statistics were reported as %(frequency) for categorical variables and mean(SD) or median(min-max) for continuous variables.

Inferential statistics were reported using Pearson’s Chi-square test to compare the difference in proportions between categorical variables. Chi Square was reported as $x^2(DF) = \chi^2$ (where DF=degrees of freedom).

Non-parametric tests were used to analyse the data which was not normally distributed. The Mann-Whitney U test was used to compare mean ranks for the combined number of those who agreed and strongly agree with the Likert scale questions 1 to 19 against the three knowledge questions regarding alarm fatigue (i.e. A. Are you familiar with the term alarm fatigue? B. Do you know
what causes it?; C. Do you know how to prevent it?). The level of significance was based on an alpha value of 0.05 and a confidence interval of 95%.

The Likert scale was scored as strongly agree = 1, to strongly disagree = 5. The number of nurses who strongly agreed and agreed were added to derive one value for those in agreeance, and one value for those who disagreed or strongly disagreed reported as %\(n\).

Given that the sample population from site A was characteristically different to the sample population from all the other sites, significant data that emerged was compared by examining Site A in isolation and contrasting findings against the remaining population and anomalies reported.

Qualitative data from the open-ended question was analysed using inductive qualitative content analysis as described by Elo and Kyngäs, (2008). Each comment was treated as one meaning unit. The comments were read several times to identify categories within the manifest content and themes and recurring themes within the latent content. Identified categories were colour coded. Validation of content categorisation was sought from a senior ICU nurse who reviewed the comments and their categorisation.

**Findings**

**Sample and response rate**

A response rate of 66.4% (\(N=166\)) was achieved across the six hospital sites (Table 1) representing approximately 12% of critical care nurses within the national Health Service Executive in Ireland (HSE, 2014). A high proportion of
the respondents were female 88.5\%(n=146), while 11.5\%(n=19) were male. The majority were staff nurses, 93.3\%(n=154), while 6.7\%(n=11) were Clinical Nurse Managers (CNMs).

The sample illustrated a well-educated workforce. The majority of the respondents 66\%(n=108) were educated to postgraduate (Higher diploma or Diploma) level, and of these, 10.4\%(n=17) had a master’s degree. Twenty-seven percent (n=45) of respondents held a degree and 6.7\%(n=11) held a registration certificate in general nursing. The respondents were also highly experienced with 61.6\%(n=98) claiming 11 years or more critical care experience.

A total of 27\%(n=45) respondents provided comments to the open question, with 49\%(n=22) of the comments from site A. The minimum level of respondent experience was one year, and the maximum was 30 years. The mean level of experience was 13 years. There was a total of 1400 words in the qualitative data, with responses ranging from 3 to 167 words averaging 28 words in length. Five core categories were identified.

**Knowledge of alarm fatigue**

The majority of nurses 87.9\%(n=146) stated they were familiar with the term alarm fatigue. Similarly, 83.6\% 83.8\%(n=138) said they knew what caused alarm fatigue. However, when their knowledge level was explored further only 47.9\% 47.5\%(n=79) stated they knew how to prevent alarm fatigue, while 52.1\%(n=86) did not know, or were uncertain how to prevent alarm fatigue.
The percentage of nurses who claimed to know how to prevent alarm fatigue 47.9%, (n=79), matched the total percentage of nurses 47.9% (n=77) who agreed that alarm management practices within their area followed best available evidence to prevent patient adverse events. A Mann-Whitney U test revealed a statistically significance difference (p= 0.038) in the mean ranks [medians] for this finding, 52 [1] vs 65 [2] (Table-2).

There was no association between nurses’ knowledge of how to prevent alarm fatigue and years of experience, educational level, Joint Commission International (JCI) hospital experience, overseas experience, gender, job title, or department.

The majority of the 79 nurses who knew how to prevent alarm fatigue were from site A, (the largest study site) 61% (n=46) vs. 37% (n=33), this finding was statistically significant, \(X^2(2) =14.4, p = < 0.001\).

A Mann-Whitney U test compared the mean ranks for the combined number of nurses who agreed or strongly agreed with the Likert scale questions, 1 to 19, against the three AF knowledge questions (questions 3, 8 & 18) (Table 2).

Nurses who were familiar with the term AF agreed that non-actionable nuisance alarms occurred frequently, (U=783, p= 0.005) and that alarms in their area were adequate to alert staff of actual or potential changes in a patient’s condition, (U=727, p=.024). Nurses who knew what caused AF agreed that non-actionable/nuisance alarms occurred frequently (U=824, p= 0.019) and those familiar with how to prevent AF agreed that management practices within
their area incorporated best available evidence to prevent patient adverse events (U=1044, p= 0.038).

There was almost unanimous agreement among the nurses in this study (99.4%, n=164) that alarms should indicate alarm priority.

**Alarm Parameters/ Settings and Checks**

Respondents were asked to rate 9 issues which inhibit effective alarm management ranking each issue from 1 (most important) to 9 (least important). Difficulty setting alarm parameters was queried in question 1 (Table 3) and question 6 in the Likert items. Both generated low levels of agreement 30.9% (n=50). The 4th highest ranking statement generated 88.4% (n=145) agreement, with nurses indicating that their practice is to customise patient alarm parameters on shift commencement and accordingly throughout the day. Documenting that alarm settings are set and appropriate for each patient generated the 6th highest level of agreement, 82% (n=134). Support for setting alarm parameters was evident in comments offered:

“I believe if alarm parameters are reviewed and set at the beginning of your shift appropriate to the patient – you eliminate most nuisance/non actionable alarms- which are the most common alarms throughout the shift.” (Respondent 66/Site F).

“Each nurse to adequately set alarm limits and change accordingly as condition changes during the shift”. (Respondent 126/ Site A)

However there was a lack of consistency in the approach to setting alarm parameters and respondents believed this was due to nurses’ inexperience:
“Alarm parameters are being set too “tight” Some ICU nurses are their own enemy, continued alarms sounding is usually a sign of an inexperienced ICU nurse” (Respondent 78/ Site F).

“A high amount of junior staff on duty who set their alarm limits tight/close together means more frequent alarms” (Respondent 26/Site C).

A Chi-square test revealed that nurses who knew how to prevent alarm fatigue customised patient alarm parameters at the beginning of a shift and adjusted accordingly throughout the day. There was a significant difference between those who knew how to prevent AF (n=72, 92%) versus those that did not (n=35, 95%) vs. those unsure (n=37, 77%) and those who claim to customise alarm parameters (n=145, 88%), $\chi^2(10.2)$, df=4.

**Education, Training and Improvement Initiatives.**

Half of the sample 50.3% (n=81) stated that their area had instituted clinical alarm improvement initiatives in the preceding two years, while 49.6% (n=80) stated that there had been no such initiatives or they were unsure. Respondents also confirmed new technology had been instituted to improve clinical alarm safety in their area, 46.6% (n=76), while 53.4% (n=87) chose a ‘no’ or ‘unsure’ response.

Many comments pertaining to training and education were offered. Nurses called for “more training” and ”ongoing training”. With “more awareness around the issue of alarm fatigue” (Respondent 121/ Site A), and “Not enough focus on teaching ‘alarm checks’ & ‘alarm settings’ as a priority at the beginning of shift” (Respondent 26/ Site C).
Moreover, the complexity of the monitoring devices and added role of technician was acknowledged in the comments calling for, “Adequate training on monitors and devices and frequent updates” (Respondent 124/Site A).

Nurses believed smart alarm technology which uses multiple parameters in alarm algorithms would be effective at reducing false alarms 72.2% (n=117) and would improve clinical response to important alarms 71% (n=115). The item achieving the lowest level of agreement, ranking 19th, stated that newer monitors had solved most problems experienced with clinical alarms 17.8% (n=29). Effective use of clinical policies and procedures regarding alarms returned the second lowest agreement ranking 18th with 30.8% (n=50).

**Noise Pollution**

Likert questions, 9, 12, and 13, and scale questions 2 and 8 (Table 3) pertained to difficulty discerning alarms due to noise levels. A low percentage of nurses 36% (n=59) agreed that alarms frequently could not be heard or were missed. However 62% (n=102) felt that environmental background noise had interfered with alarm recognition while 50% (n=82) felt there was confusion when discriminating which device was alarming.

Respondents recognised noise as the toxic by-product of ineffective alarm management and acknowledged the sensory strain imposed by excessive alarms:

“Biggest issue is noise levels and being able to hear alarms up to several hours after finishing a shift” (Respondent 102; Site A).

“Reducing noise levels overall in ICU/HDU e.g. Alarming equipment, phones, conversation, television and radio” (Respondent 8/ Site B).
Too Many False Alarms

The second, third, and seventh highest level of agreement in order, was that nuisance alarms are frequent 90.2% (n=148), disruptive to patient care 90.6% (n=145), and reduced trust in alarms causing nurses to sometimes disable alarms 80.5% (n=132). The highest ranking obstacle to effective alarm management was the frequency of false alarms causing a subsequent reduced attention and response to alarms. Respondents expressed feelings of being over burdened by frequent false and unnecessary alarms:

“Too many alarms are not necessary but everyone i.e. managers, IT, Bioengineering, companies that supply machines are covering themselves legally” (Respondent 125/Site A).

“Many ‘Alarms’ are Ridiculous and should always be turned off such as temperature cvp (multiple false alarms) etc. etc.” (Respondent 69/Site F)

“An alarm should mean that something is wrong and needs attention, they shouldn’t be sounding without good reason” (Respondent 78/Site F)

Staffing

Nurses agreed that clinical staff were sensitive to alarms and responded quickly 76% (n=123). However frequent false alarms was the highest ranked obstacle to effective alarm management causing a performance decrement in staff with reduced attention or response to alarms. This was followed by inadequate staff to respond to alarms as they occur (ranked no. 2) and over-reliance on alarms to alert staff to patient problems (ranked no. 3) (Table 3). The inability of staff to
answer numerous alarms whilst simultaneously accomplishing their duties was also evident from the comments offered.

“Staff aim to answer alarms however some task priorities may not allow decent alarm vigilance” (Respondent 124/Site A)

During periods of staff dilution such as meal relief, staff shortages the burden of high alarm loads was more acutely felt.

“Alarm management where ratios become dilute, e.g. Transfers/critically ill dependent patients/breaks/staff shortages/patient dependency e.g. dependence on ADL”. (Respondent 128 Site/ A)

“Adequate staff (Break times difficult to answer numerous alarms)” (Respondent No129/Site A).

“Adequate staffing reduces reliance on alarms” (Respondent 69/Site F).

Alarm related patient adverse events

Adverse patient events in the past five years related to clinical alarms were reported by nurses from all study sites 54% (n=88). The majority 94.7%. (n=71) reporting adverse events were from the largest hospital (Site A) with the remaining 19.3 % (n=17) from the other sites. A Pearson’s Chi-square test showed that this result was significant; $\chi^2 93.3$ (df=2), p= 0.0001, 95% (n=71) vs.19% (n=17).

Although not statistically significant, among the 71 respondents from Site A who affirmed that their hospital had experienced adverse patient events due to alarms, 36.6% (n=26) did not know or were unsure how to prevent alarm fatigue. Among the 10 respondents from Site D who reported adverse events, only one of those respondents stated they knew how to prevent alarm fatigue. A chi-square test (likelihood ratio) was performed revealing a significant p-value $\chi^2$ (26) (df=10), p=0.004, 54.5% (n=48) vs 45% (n=40) for this finding.
Discussion

To our knowledge, this is the first European study to report critical care nurses’ knowledge of alarm fatigue and reported practices toward alarms. This is not surprising as the topic is in its infancy (Paine et al., 2016).

The majority of nurses claimed they were familiar with the term alarm fatigue and knew what caused it. To minimise acquiescent response bias, the third question queried whether nurses knew how to prevent AF. Over half of the respondents stated they did not know or were unsure how to prevent AF. This is of concern as evidence based recommendations to limit AF are widespread throughout the literature.

The majority of respondents claiming to know how to prevent alarm fatigue were from site A, 58% (46). The advanced knowledge level of nurses at this site could be explained by an intensive initiative incorporating education and practice change within critical care in response to two alarm-related deaths at the site. However, 39% (n=29) of 75 respondents from site A did not know or were unsure how to prevent alarm fatigue. This would suggest that efforts to improve clinical alarm management through education have not been completely successful. Among the 10 respondents from Site D who reported adverse events, only one of those respondents stated they knew how to prevent
alarm fatigue (p=0.004). This is a concern as it would suggest that staff at site D are lacking in knowledge regarding measures to safeguard against alarm related adverse events.

Respondents agreed unanimously that alarm sounds or visual displays should indicate alarm priority. Alarm annunciations of therapeutic devices which do not match the criticality of the situation continues to be an issue (Edworthy, 2013). Furthermore, alarm sounds are often difficult to localise and discriminate whilst having no urgency mapping or priority encoding (Edworthy and Helier, 2005). Matching alarm priority to the clinical situation is a recommendation of ECRI (2015).

Responses in this study were compared against Cho et al's., (2016) South Korean Study and a data subset for both the HTF 2006, and 2011(Funk et al., 2014) studies which isolated ICU nurses. The level of agreement for the Likert scale questions numbered 1-19 reported here are similar to those reported by ICU nurses in the HTF surveys (2006 and 2011) and Cho et al’s (2015) study. The vast majority (99%) of nurses in this study and 95% of ICU nurses studied in America and South Korea agreed that alarms should indicate alarm priority. Across all studies 79 to 81% of nurses agreed that alarms are being disabled due to trust erosion in the alarm system. Research affirms that improving alarm reliability increases alarm response (Bliss and Dunne, 2000; Bliss et al 1995 Rayo and Moffatt-Bruce, 2015). Alarm customisation may increase trust in alarms and education strategies may improve response however they are not a panacea (Sowen at al 2015; Yue et al 2016).
Difficulty understanding the priority of an alarm was ranked in the top four across all studies. Inadequate staff to respond to alarms was ranked number two in this study and number three in the South Korean study and number 6 among HTF 2006/2011 ICU nurses (Table 3).

Alarm loads from the physiological monitor at site A had been reported as 30,000 per week between ICU and HDU (17 beds) (Geraghty, 2015). This equals approximately one alarm every 20 seconds from the monitor alone. Alarm floods are defined by the American National Standards Institute/International Society of Automation (ANSI/ISA 18.2 ) as more than 10 annunciated alarms per operator in a 10-minute period. Therefore staff at Site A were operating in a state of continuous alarm flood. In the scenario of alarm flood, attention demands outstrip resources, and sensory overload results in failure to prioritise and effectively manage alarms, causing real or significant events to be missed. Broad agreement exists that alarm loads of this magnitude exceed the cognitive processing capacity of an individual. Consequently alarm floods are classified as extremely hazardous and undesirable by other high-risk industries. Furthermore, in critical care environments, nurses are faced with numerous sensory stimuli that compete for attention. Simon (1996) noted that designers of information systems inherently failed when they sought to provide more information instead of filtering out irrelevant and unimportant information. This is echoed in the qualitative
comments in this study with a call for “less busy monitors”. Moreover, it is highlighted that junior nurses are often overwhelmed by clutter on monitor displays (Drews, 2008). The aviation industry have recognised the effects of excessive sensory stimuli on cognitive performance in pilots and introduced controls to attenuate the negative psychological effects. This included equipping cockpits with a ‘declutter mode’ to reduce the number of displayed instruments vying for attention (Rash, 2012).

Within the qualitative comments, nurses recognised their lack of knowledge regarding complex technology calling for additional training. International literature suggests that practitioners are often unaware of the intricacies of monitors (ACCE, 2007, Borowski et al., 2011; FDA, 2011, Harris et al., 2011 Keller, 2012;) and tend to underestimate their knowledge deficits (ACCE, 2007). Even experienced nurses need ongoing education regarding medical devices (AACN, 2013; Cvach et al., 2013).

In this study, the majority of nurses felt that non-actionable alarms occurred frequently and disrupted patient care. Although it is known that most alarms are non-actionable, Paine et al (2016) conclude that there appears to be a relationship between alarm exposure and response time that could be caused by alarm fatigue. However, it is not known which interventions are the most effective in reducing the number of unnecessary alarms safely (Paine et al., 2016). The Joint Commission Sentinel Event Alert (2013) details alarm management errors involved in reported adverse events as, inappropriate alarm settings, alarms switched off, and inaudible alarms. Alarm fatigue, insufficient staffing, poor staff education and lack of customisation of alarms were cited as
contributing factors. Among the recommendations for practice were implementation of leadership and organisational planning to devise guidelines for alarm setting, and training and education for staff.

This study provides evidence that according to nurses’ perceptions, the Joint Commission alarm management errors and conditions that give rise to alarm fatigue (i.e. noise pollution, white noise, high alarm load, frequent nonactionable alarms, alarm floods and poor alarm design) are a feature of critical care departments in Ireland. Moreover, this study provides evidence that adverse events related to clinical alarms are occurring, as all sites studied reported patient adverse events related to clinical alarms. The reports of adverse events (Geraghty, 2015) likely do not reflect the entire number of near misses which may have occurred due to alarm mismanagement.

While it is important that healthcare practitioners recognise and identify when alarm fatigue is a key causal factor in sentinel event analysis, nurses should guard against neglecting the factors that perpetuate AF, such as poor staffing and prohibitive alarm policies that prevent staff from adjusting alarm volumes or limits. Given that AF is a complex, multifactorial problem, examination of associated sentinel events requires a broad outlook defining circumstances that contribute to its development.

**LIMITATIONS**

The study was confined to the West of Ireland limiting generalisability of findings. Furthermore, site A is distinctly different from the other sites, as it is significantly larger and is the only model 4 hospital in the region. The adoption
of recommended ECRI alarm management practices within critical care departments is unique to this site making it characteristically different from the other hospitals in the study.

The HFT instrument used in this study assesses nurses' perceived views of alarm management in their area rather than the actual occurrence of alarm fatigue in clinicians. Moreover, the psychometric properties of the HTF instrument have not been rigorously tested or evaluated leaving uncertainty regarding the findings generated using the tool. Recent developments on a new tool to measure alarm fatigue have revealed promising results. Torabizadeh et al., (2016) report good internal homogeneity and retest methods for their alarm fatigue questionnaire.

**CONCLUSION**

The full extent of the phenomenon of alarm fatigue has not been properly considered or realised outside the US. The alarm fatigue phenomenon has serious consequences for patient safety with the worst-case scenario resulting in death or serious patient harm. An environment of excessive alarms is conducive to error. Moreover, the burden of responding to numerous non-actionable alarms drains nursing resources. The findings suggest that the majority of nurses are unaware of current evidence-based approaches to reduce non-actionable alarms attenuating alarm fatigue.

Future research should focus on identifying levels of alarm fatigue among critical care nurses and evaluating education and training approaches to manage alarm fatigue. One site in this study had suffered patient deaths
attributed to alarm fatigue. Monitor alarm loads at this site were reported at levels in excess of three per minute, defined as alarm flood by the ANSI/ISA 18.2 guidelines. When the other myriad alarms that feature in ICU are considered such as ventilator, dialysis, and fluids pumps, alarm loads easily outstrip physical and cognitive resources necessary to process alarms leading to compromised patient safety.
REFERENCES


Funk M, Clark JT, Bauld TC, Ott JC, Coss P. Attitudes and practices related to clinical alarms. American Journal of Critical Care 2014;23(3).


Patterson, R.D. Guidelines for auditory warnings systems on civil aircraft. Civil Aviation Authority paper; 1982 82017: Civil Aviation Authority: London.


