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Critical care nurses and their clinical reasoning for customizing monitor alarms: a mixed-method study

Original article

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Abstract: **Objective:** To explore the clinical rationale of critical care nurses for personalizing monitor alarms. One of the most crucial jobs assigned to critical care nurses is monitoring patients' physiological indicators and carrying out the necessary associated interventions. Successful use of equipment in the nursing practice environment will be improved by a thorough understanding of the nurse's approach to alarm configuration.

Methods: A mixed-method design integrating quantitative and qualitative components was used. The sample of this study recruited a convenience sample of 60 nurses who have worked in critical care areas. This study took place at Lebanese American University Medical Center Rizk Hospital, utilizing a semi-structured interview with participants.

Results: The study demonstrated the high incidence of nuisance alarms and the desensitization of critical care nurses to vital ones. According to the nurses, frequent false alarms and a shortage of staff are the 2 main causes of alarm desensitization. Age was significantly associated with the perception of Smart alarms, according to the data ($P = 0.03$). Four interconnected themes and subcategories that reflect the clinical reasoning process for alarm customization were developed as a result of the study's qualitative component: (1) unit alarm environment; (2) nursing style; (3) motivation to customize; and (4) clinical and technological customization.

Conclusions: According to this study, nurses believe that alarms are valuable. However, a qualitative analysis of the experiences revealed that customization has been severely limited since the healthcare team depends on nurses to complete these tasks independently. Additionally, a staffing shortage and lack of technical training at the start of placement have also hindered customization.

Keywords: *customization • critical care unit • equipment • mixed method • monitor alarm • motivation • nurse's perception • practice environment*

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1. Introduction

One of the most crucial duties assigned to critical care nurses is to keep track of a patient's physiological parameters such as heart rate, oxygen saturation, and cardiac rhythm and carry out the necessary associated interventions.[1] In the majority of intensive care units (ICUs) as well as many hospital units, monitoring is aided by cutting-edge technologies, including bedside clinical equipment.[2] Nurses always rely on warnings from these devices to alert them to changes in the status of the patient and to direct their attention to them (Ruppel et al., 2019). The goal of physiological monitoring alarms is to increase patient safety by informing clinicians of changes in patient's health and technical problems; however, <15% of monitoring alerts in ICUs may be accurate or immediately useful for patient care (Bonafide, Lin, Zander et al., 2015; Bonafide et al., 2017; Drew et al., 2014; Paine et al., 2016).

Alarm fatigue is a condition in which nurses are more prone to think that alerts are not genuine or important as a result of receiving an excessive number of meaningless and false warnings.[3] In a study that was performed by Simpson and Lyndon,[4] they reached to a general agreement that false alarms, having too many alarm-generating equipment, and the fact that most alarms lacked clinical value all contributed to alarm fatigue. The vast majority of the alarms did not add to the clinical assessment or planned care by the nurses, but it was found that they instantly responded to certain other alarms. Sendelbach and Funk[5] and the Joint Committee (2013) have reported that alarm fatigue will lead to delayed reactions to alarms and missing true incidents, potentially compromising patient health. One technique to minimize the number of alarms and increase their usefulness in patient safety is the modification of tracking alarm settings to match specific patient needs, often referred to as modifying, tailoring, or individualizing alarms. Customizing alarms has its place since it enables the nurse to decide which alarm settings are best for each patient, reducing the number of pointless alerts while increasing the likelihood that clinically meaningful events will send off an alarm. Instead of using the default settings, the alarm settings can be changed to reflect the patient's physiological monitor readings from their bedside, which will produce alarms that are more useful for patient follow-up.[6] As a result, the correct configuration of alerts increases the nurse's ability to track and collect vital parameters on their patients. Customized alarm settings have also been associated with lower workloads than default alarm settings.[7]

As healthcare technology advances, it is necessary to customize the global system based on the preferences of specific patients to increase product effectiveness and alarm specificity.[8] For example, Ruppel et al.[9] reported that nurses' configuration of physiological monitor alert settings is an example of how nurses communicate with devices that allow configuration.

The configuration of alerts is not usually done in ICUs, despite the body of literature demonstrating that tracking alarms are frequently clinically useless[10,11]; nonetheless, there is no information regarding when and how nurses configure alarms. Hence, this study aims to explore the critical care nurses' clinical reasoning towards monitor alarm customization, in which the study hypothesized that Intensive care alarm fatigue has set in for nurses as a result of constant monitor alarms.

2. Methods

2.1. Study design

A non-experimental mixed methodology was used. A qualitative approach was utilized to gather thorough information and patterns regarding nurses' opinions of the issue at hand, while the quantitative survey was used to assist in providing an unbiased picture of the nurses' attitudes toward monitor alarms and the clinical justification for alarm customization.

2.2. Settings and sampling

The Lebanese American University Medical Center Rizk Hospital in Beirut, Lebanon, was the site of this study's critical care units. The hospital had a space capacity of 130 beds. Neonatal intensive care unit (NICU), cardiac care unit (CCU), cardiac surgery unit (CSU), pediatric intensive care unit (PICU), neonatal intensive care unit (NICU), and ICU were among the critical care specialties represented in the study's sample of nurses. The inclusion criteria of this study include nurses who (1) worked in the critical care areas, (2) had an experience of >6 months, and (3) agreed to participate in this study.

2.3. Instruments

Demographic characteristics including age, gender, clinical experience, job title, and hospital department were among the general characteristics that were collected from the participants.

To assess the background of participants with clinical alarms, the health technology foundation and the clinical alarms survey were used. These were followed by 20 general statements on patient alarms, which asked participants to score their degree of compliance with the assertion using a 5-point Likert scale

(5 = strongly agree, 4 = agree, 3 = neutral, 2 = disagree, and 1 = strongly disagree). The next part covered 4 concerns relating to the frequency of adverse accidents, the use of monitor sensors, system enhancement measures, and emerging technical approaches for system control. The final section presented a list of 9 problems that could theoretically hinder the successful monitoring of clinical alarms. Respondents ranked the issues using a scale of 1 = most important to 9 = least important. The inter-rater reliability was proven previously by multiple studies,[12,13] and one of the most prominent was done by Honan et al.[14] who showed it to be 87.0.

To compile information on nurses' impressions about monitor alarms and their clinical justifications for customizing alarms, a semi-structured interview was conducted using open-ended questions (Table 1).

2.4. Data collection procedure

After completing the alarm survey questionnaire to learn more about their impressions of monitor alarms and their clinical justifications for customizing alarms, a semi-structured interview was conducted after 1 week of collecting the survey data. The interviews were planned at an appropriate time for nurses, and they were informed that this interview was entirely private and that any verbatim recordings would not reveal them by name; instead, the data were coded for secrecy. Additionally, respondents were informed that they might leave the study if they felt the need. The interview was recorded and translated, and the respondents were informed that it was handled securely and that only the interviewer had access to the recordings. Each interview was given a set allotment of time—roughly 30 min—to gather data. After the data were combined, a theme analysis was conducted.

No.	Interview questions
1	How do monitoring alarms affect your practice? What is the role of monitor alarms in your practice?
2	What is your perception of the number of monitor alarms on your unit?
3	What do you see as the benefits and challenges of the alarms on your unit?
4	Who responds to alarms on your unit? What factors do you think affect your response to alarms? When do you communicate with other nurses about your alarm settings? What policies and procedures, official or unofficial, exist on your unit related to alarms? How did you learn to use the monitors? How does the acuity of the patient influence your alarm management?
5	What do you see as the purpose of customizing alarms? How often do you need to customize alarms from the default settings? What types of alarms do you think you customize most often? One way people sometimes customize alarms is by changing the alarm limits. If you decide an alarm limit needs to be customized, how do you determine how much to change the limit?
6	What does the term alarm fatigue mean to you?

Table 1. Interview schedule.

2.5. Maintaining the rigor

The concepts that emerged from the theme evaluation were put through a parallel analysis to make sure they remained accurate and relevant in the context of the findings and reflected a clear understanding of the experiences of nurses. Both participants were met on the same platform at a convenient time, and the inspectors spoke to them both in a friendly. The interviewer asked the same questions, covered all relevant subjects, and did not exclude any information from the interviews. The study's conclusions were supported with clear verbatim quotes, giving the study's participants a sincere voice.

2.6. Ethical considerations

This study was approved by the ethics committee of the Lebanese American University's institutional review board (IRB) (Approval No.: LAUMCRH.KD1.2/Apr/2020). All patient data have been kept anonymous and confidential. The nurses gave their informed consent so that the necessary data could be collected. The audio files and survey responses were kept in a computer file that was password-protected and encrypted and could only be accessed by the principal investigator, and audio files were erased after reading.

3. Results

3.1. Quantitative analysis

3.1.1. Participant characteristics

The sample consisted of 60 registered nurses, and $n = 40$, 66.7% of them were female. Their ages ranged from 18 years to 51 years, with a mean age of 26.2 years (standard deviation [SD] = 7.16). The range of years of experience was 6 months to >10 years, with a mean of 6.4 years (SD = 7.70). The majority of the nurses ($n = 26$, 43.3%), ($n = 21$, 35.0%) worked in the ICU and NICU, respectively, with the remaining nurses working in the CCU, Neuro-ICU, and PICU (Table 2).

3.1.2. Alarm perception and practice

The clinical Alarm Survey Questionnaire grouped the 5 respective subthemes: nuisance alarms, experience with alarms, alarm notification, smart alarms, and institutional requirements.

Variable	*N* (%)	*M* (SD)
Gender		
Male	20 (33.3)	
Female	40 (66.7)	
Age (years)		26.2 (7.16)
18–25	31 (51.7)	
25–30	18 (30.0)	
30–35	7 (11.7)	
35–45	2 (3.30)	
>45	2 (3.30)	
Years of experience		6.4 (7.70)
0.5–1	6 (10.0)	
1–3	25 (41.7)	
3–6	9 (15.0)	
6–10	13 (21.7)	
>10	7 (11.7)	
Department		
ICU	26 (43.3)	
Neuro ICU	5 (8.30)	
CCU	6 (10.0)	
NICU	21 (35.0)	
PICU	2 (3.30)	

Note: %, percentage; CCU, cardiac care unit; ICU, intensive care unit; *M*, mean; *N*, number; NICU, neonate intensive care unit; PICU, pediatric intensive Care Unit; SD, standard deviation.

Table 2. Sociodemographic data.

When >90% of respondents selected "Strongly Agree" and "Agree," very high agreement percentages were given; high and majority agreements were given when 66%–89% selected "Strongly Agree" and "Agree." Low agreement (33%–49%), and extremely low agreement (33%) were the 2 categories used to classify low agreement ratings. For instance, only 2 survey items from the subtheme of "Experience with alarm" in this study had a proportion of agreement of 90.0%. In addition, the majority of respondents indicated high agreement (66%–89%) and majority agreement (50%–65%) percentages to the majority of survey questions, indicating that they strongly and unanimously concur with institutional requirements, nuisance alarm, alarm notification, and smart alarm questions. A total of 4 questions on experience with alarms showed low agreement (33%–49%), with percentages ranging between 38.3% and 48.3%, but no question had very low (33%) agreement percentages (Table 3).

Ranks were assigned to these percentages based on the average of the entire response. According to the descriptive analysis, the nurses who took part rated "Frequent false alarms, which result in reduced

Questions	Clinical alarms survey (n = 60)
Nuisance alarms	
Nuisance alarms occur frequently	68.3
Nuisance alarms disrupt patient care	72
Nuisance alarms reduce trust in alarms and cause caregivers to turn alarms off at times other than setup or procedural events	61.7
Experience with alarms	
Properly setting alarm parameters and alerts is overly complex in existing devices	38.3
New (<3 years old) monitoring systems have solved most of the previous problems we experienced with clinical alarms	58.3
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	81.7
There have been frequent instances where alarms could not be heard and were missed	40
The staff is sensitive to alarms and responds quickly	71.7
When several devices with alarms are used with a patient, it can be confusing to determine which device is in the alarm	45
Environmental background noise has interfered with alarm recognition	48.3
Alarm sounds and/or visual displays should differentiate the priority of the alarm	90
Alarm sounds and/or visual displays should be distinct based on the parameter or source (e.g. device)	83.3
Alarms should impact multiple senses (audible, visual, proprioceptive, etc.)	90
Alarm notification	
The purpose of clinical alarms is to alert staff of an existing or potentially hazardous patient condition	88.3
The medical equipment used on my unit/floor all have distinct outputs (sounds, repetition rates, visual displays, etc.) that allow differentiation of the source of the alarm	61.7
A central alarm management staff that receives alarm messages and notifies the appropriate staff is helpful	75
Alarm integration and communication systems via pager, cell phone, and other wireless devices are useful in improving alarm management and response	65
Smart alarms	
Smart alarms, where multiple parameters, rate of change of parameters, and signal quality, are automatically assessed in their entirety would be effective in reducing false alarms	63.3
Smart alarms, where multiple parameters, rate of change of parameters, and signal quality, are automatically assessed in their entirety would be effective in improving clinical response to important patient alarms	71.7
Institutional requirement	
Policies and procedures exist within the facility to regulate alarms and they are followed	60

(*Continued*)

Table 3. Continued

Questions	Clinical alarms survey (n = 60)
There is a requirement in your institution to document that the alarms are set and are appropriate for each patient	70

Table 3. Clinical alarm survey results compared with published studies.

No.	Variables	Mean	Ranking
1	Difficulty in setting alarms properly.	3.92	7th
2	Difficulty in hearing alarms when they occur.	3.58	3rd
3	Difficulty in identifying the source of an alarm.	3.82	5th
4	Difficulty in understanding the priority of an alarm.	4.00	8th
5	Frequent false alarms, lead to reduced attention or response to alarms when they occur.	3.32	1st
6	Inadequate staff to respond to alarms as they occur.	3.321	2nd
7	Over-reliance on alarms to call attention to patient problems.	3.73	4th
8	Noise competition from non-clinical alarms and pages.	4.08	9th
9	Lack of training on alarm systems.	3.87	6th

Table 4. Ranked issues of importance regarding alarms.

attention or response to alarms when they occur" as the most critical factor and "Noise competition from non-clinical alarms and pages" as the least important (Table 4).

3.1.3. Differences in alarm's perception, practice, and importance Based on participant characteristics

To ascertain whether there are any gender-specific differences in alarm practice and perception, an independent *t*-test was conducted. With a *P*-value of ($P = 0.02$) and ($P < 0.001$), respectively, the results for the questions "Properly setting alarm parameters and alerts are overly complex in existing devices" and "Environmental background noise has interfered with alarm recognition" showed a highly significant difference in the level of experience with alarms; a significant difference on the level of "Difficulty setting alarms properly" and "Difficulty hearing alarm when they occur" with a *P*-value of 0.05 and 0.02, respectively. Otherwise, no significant observations were noted (Table 5).

To determine whether there are any statistically significant differences in alarm perception and practice

Variables	*M* (SD)	*t*	*P*-value
Properly setting alarm parameters and alerts is overly complex in existing devices			0.02*
Male	3.80 (1.64)	2.33	
Female	2.75 (1.65)	2.33	
Environmental background noise has interfered with alarm recognition			0.01*
Male	4.10 (1.37)	2.47	
Female	2.95 (1.84)	2.72	
Difficulty in setting alarms properly			0.05*
Male	3.10 (1.92)	−1.8	
Female	4.33 (2.71)	−2.02	
Difficulty in hearing alarms when they occur			0.02*
Male	2.85 (1.95)	−2.09	
Female	4.30 (2.78)	−2.34	

Note: SD, standard deviation; **P* is significant at 0.05.

Table 5. Difference of means in alarm's perception and practice according to gender.

according to age, years of experience, and distinct hospital departments, an Analysis of variance (ANOVA) test was conducted. According to the data shown in Table 6, there were no significant variations in the number of nuisance alarms ($P = 0.56$), alarm experience ($P = 0.37$), alarm notification ($P = 0.79$), smart alarms ($P = 0.23$), or institutional requirements ($P = 0.52$) by age. The presence of any variations between the participants based on their varied years of experience on the level of alarm's perception and practice was also examined with, however, no appreciable variations found. For the hospital department, there were no significant differences in the level of nuisance alarm ($P = 0.44$), experience with alarm ($P = 0.40$), alarm notification ($P = 0.47$), Smart alarms ($P = 0.76$), and institutional requirements ($P = 0.29$) (Table 6).

The ANOVA test, however, also reveals significance on the level of rating the importance of "difficulty in setting alarm properly" and "difficulty in understanding the priority of an alarm" with *P*-values of 0.05 and 0.01, respectively, and no other significances were noted with other questions. However, a significant difference exists between age groups regarding rating the importance of alarms with a *P*-value of 0.03. However, even though there are no significant differences between years of experience when rating the importance of alarms ($P = 0.12$), the ANOVA test revealed a highly significant difference in the level of "difficulty in setting alarm properly" and "difficulty in hearing alarms when they occur," with *P*-values of 0.01 and $P < 0.01$, respectively. With a

Variable	df	*M*	*F*	*P*-value
Age				
Nuisance alarms			0.75	0.56
BG	4	2.01		
WG	55	2.69		
Experience with alarms			1.09	0.37
BG	4	32.87		
WG	55	30.15		
Alarm notification			0.42	0.79
BG	4	2.35		
WG	55	5.6		
Smart alarms			1.47	0.23
BG	4	2.33		
WG	55	1.59		
Institutional requirements			0.82	0.52
BG	4	2.41		
WG	55	2.92		
Years of experience				
Nuisance alarms			1.02	0.41
BG	4	2.68		
WG	55	2.64		
Experience with alarms			1.11	0.36
BG	4	33.34		
WG	55	30.12		
Alarm notification			0.29	0.88
BG	4	1.65		
WG	55	5.65		
Smart alarms			1.53	0.21
BG	4	2.42		
WG	55	1.59		
Institutional requirements			0.54	0.71
BG	4	1.6		
WG	55	2.98		
Hospital Department				
Nuisance alarms			0.96	0.44
BG	4	2.53		
WG	55	2.65		
Experience with alarms			1.02	0.4
BG	4	30.98		
WG	55	30.29		
Alarm notification			0.91	0.47
BG	4	4.93		
WG	55	5.42		
Smart alarms			0.47	0.76
BG	4	0.8		
WG	55	1.7		
Institutional requirements			1.29	0.29
BG	4	3.65		
WG	55	2.83		

Note: BG, between groups; WG, within groups.

Table 6. Difference of means in alarm's perception and practice according to age, years of experience, and hospital department.

P-value of 0.38, no variations between hospital departments regarding the significance of alarms were also discovered (Table 7).

3.2. Qualitative analysis

To gain a deep understanding of the clinical perception of alarm customization and alarm fatigue, a semi-structured interview was conducted with 8 nurses when the data reached saturation. Transcripts were axially coded, and then the concepts were categorized. Four themes were built from subthemes, namely (1) unit alarm environment; (2) nurse style; (3) motivation to customize; and (4) clinical and technological customization. The concept map is shown in Figure 1,

3.2.1. Unit alarm environment

The "alarm environment," or the setting that describes how nurses will manage their alerts, serves as the conceptual model's background. Five characteristics were identified and shown to have contributed to the unit alert environment, according to the nurses' comments in the interviews, namely, case-by-case, teamwork, type of care, patient–nurse ratio, chaos, and crowding.

Variable	df	*M*	*F*	*P*-value
Age				
Alarm importance ranking scale				0.03*
BG	4	547.27	2.86	
WG	55	191.3		
Difficulty in setting alarm properly				0.05*
BG	4	14.98	2.6	
WG	55	5.76		
Difficulty in understanding the priority of an alarm				0.01*
BG	4	20.88	3.61	
WG	55	5.79		
Years of experience				
Alarm Importance Ranking Scale				0.12*
BG	4	387.79	1.91	
WG	55	202.9		
Difficulty in setting alarm properly				0.01*
BG	4	20.03	3.72	
WG	55	5.39		
Difficulty in understanding the priority of an alarm				0.00*
BG	4	22.22	4.02	
WG	55	5.52		

Note: BG, between groups; WG, within groups; *$P<0.05$, 2-tailed.

Table 7. Difference of means in alarm's importance according to age, years of experience, and hospital department.

Case by case

The participating nurses have said that they often alter alerts on a case-by-case basis. Many participants based on each patient's baseline changes, since it is practically hard to standardize alerts for all patients. A nurse remarked, "It should be always on and adjusted to patient baseline but each case differs from other …" (N2). Another nurse proclaimed, "Nurses usually have to adjust alarms after special monitoring of the patient for hours so he/she could have an idea about his/her baseline and thus each patient will have different alarms limits than others, especially in ICU where each case and diagnosis differ sometimes completely from others" (N1).

Teamwork

Nurses stated that they depend on other staff members to respond to alarms. They did, however, also emphasize how frequently doctors and other medical staff who round on the units paid little to no attention to alerts and relied on the nurse to assess their significance. "We are all requested to respond Head Nurse, Registered Nurse, Practical Nurse" (N2), as well CCU nurses proclaimed "Registered nurses (RNs) mainly respond to alarms but other health care workers are also responsible" (N3), "All workers in the unit respond but usually RNs in the CCU are the first responder to alarms" (N4), Neuro ICU nurses reported, "Anyone should respond to the alarm, however working in the Neuro ICU and hear the alarm must intervene by at least knowing the cause…" (N7).

Type of care

The majority of nurses stated that not all patients respond to alarms in the same manner, which implies that nurses did not always directly intervene in alarms. A nurse's priority in responding to an alarm depends on the type of treatment that the patient needs. One of the nurse's responders declared: "Each case differs from the other, patient on palliative care any alteration in alarms will not push me to intervene or respond as I do when the patient is full code" (N5). Another nurse added in the same context: "… If I know that the patient is a very stable one and a ventricular

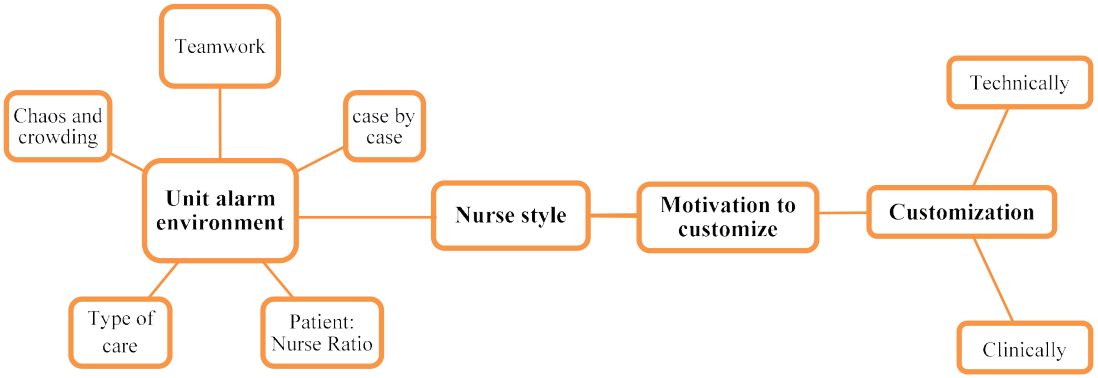

Figure 1. Phenomenological themes concept map.

tachycardia alarm signals I don't run to the patient immediately because I know from his/her past experiences that it's a faulty alarm, but if I know that the patients were unstable, a simple alarm like increase in respiratory rate (RR) or low SPO_2 level alerts me to check, assess, and report to the MD" (N6).

Patient: Nurse ratio

The patient's acuity and severity of disease could put pressure on nurses to give alarm management priority over other alerts and tasks. The response to alarms, according to one nurse, "depends on the number of patients to nurse and also on the general condition of the patient. If I know that the patient is very stable… if I know that the patient is unstable and I have another patient also heavy, a simple alarm like an increase in RR or low SPO_2 level alerts me to check, assess, and report to the MD…" (N6). Another nurse commented, "ratio plays an important role as a factor even when I look after 3 stable patients, first of all, I check their flow sheet to assess their baseline and I check alarms on my first round so I reduce any unnecessary alarms and I apply limits that it could reduce nuisance and make my shift easy" (N3).

Chaos and crowding

Some nurses claimed that their unit has an alarming culture where there are too many alarms, which is noisy. A nurse working in the CCU reported, "Chaos that might exist in the critical unit and presence of many voices and crowding in the area that might delay response" (N3). Neuro-ICU nurses insist on this idea and proclaim "In my opinion, the huge number of alarms and the frequency of its ringing, let the nurses a bit slower in intervention and taking it seriously" (N7).

3.3. Nurse style

In this study, nurses shared their experiences with alarm customization, and it was observed that each nurse has a unique style when it comes to doing so. A nurse reduced noises to the maximum and said: "According to me, I mainly think to night shift which is supposed to be a time of calm and patients have to sleep and rest where alarms intervene to cause noises and nuisance and disturb patient sleep and same apply to us where the continuous false alarm that sucks our energy and interrupt our work just to silence it. This is why I go to my stable patient who moves a lot in bed and turns off most of the alarms that are unnecessary and changes parameters to reduce alarms nuisance and artifact alarms to a minimum!" (N6). However, another nurse can't reduce in the same way but reported: "… And alarms noises are so bad for the babies, especially to premature which lead to a hearing problem which stresses you to silence the sounds pretty quickly and never neglect the alarm, and so changing parameters 10%–15% from the baseline in a way not to near miss any event" (N7).

3.4. Motivation to customize

During this study, it was discovered that nurses are sometimes prompted to adjust alarm parameters by ambient factors, as previously described, and by other colleagues: "In my 20 years of practice, I always remind new RNs who pass with me as an orientation to change the parameters of alarms; they typically need to be reminded about that in their first working months" (N2).

Other nurses were internally motivated to customize, the majority of them were senior nurses who were motivated by an internal curiosity that motivates them to customize: "By practice or by session given by biomedical team or company and personally, I am curious

I always check and go into settings to see how it works in a purpose to shed the light only on important parameters and reduce any other unnecessary noises" (N5); "… with time we discovered by our curiosity" (N1).

3.5. Clinical and technological customization

A nurse's ability to properly customize alarms and know how to alter them was established through experience and other elements connected to the patient, in addition to the preceding topic about adjusting alarms and incentives to do so.

Clinically customizing alarms depends on your patient's status and plan of care, as one nurse commented on this: "We can adjust the limits as we like so it stops to alarming and we adjusted according to patient condition and code" (N1), and another nurse said as well: "patient on palliative care any alteration in alarms will not push me to intervene or respond as I do when the patient is full code" (N5), also another nurse proclaimed: " when the patient has a high workload, that one we called the heavy case and is active usually we will be very careful when customizing limits of alarms, and cautious not to have any unnecessary alarm that could overwhelm us during duty for a false alert, however, if the patient is chronic with poor prognosis and under a palliative care, alarms usually adjusted so it doesn't bother us but alert us of fatal sudden consequence like hypotension, V-tach, V-fib, Asystole but not artifact…" (N4).

A barrier to customization, according to nurses, is to know each patient comprehensively, including his/her case, plan of care, discharge plan, and use monitors and change parameters. Almost the majority of nurses have learned to customize alarms from their preceptors and/or from company technicians; they said: "I learned to use the monitors during my orientation period when I started working also a company technician gave us an informative session about the monitors we have on the unit, the alarms and other settings as well on the central monitor" (N6), "I learn to use the monitor during the orientation session where they shed the light on the causes of alarms and alarms setting and I passed a competency test for this purpose" (N7).

4. Discussion

Customizing alarm by nurses requires their needs to have a clear motivation as well as professional and technological expertise. The findings of this study show a wide range of factors influencing how nurses customize alerts and show what is required to configure alarms effectively. However, several studies reported that ICUs and managing alarms are mostly a nursing responsibility.[15,16] As a result, understanding the clinical justification for nurses' alarm control is crucial to the advancement of alarm-related practices, policies, and programs.

According to the findings of our study, the majority of the critical care nurses reported that nuisance and false alarms commonly occur in their units, leading to the inability to prioritize their work. Additionally, the nurses stated that alarms should be able to assist nurses in indicating the priority of alerts. Nearly half of the participating nurses stated that the background noise of the critical care environment has caused them to mistake the vital alarms for the less significant ones. The results of our study also showed that the critical care nurses who participated had a favorable opinion of the utility of the alarms installed in their units and of the necessary procedures for notification, customization, and documentation. Besides, the most important 3 issues that have been documented regarding alarms are the excessive number of false alarms, inadequate staff to respond to alarms, and difficulty in hearing alarms when they occur. This result was consistent with a study that was conducted by Sendelbach and Funk,[5] which scientifically demonstrated that the majority of monitor alarms are erroneous and alarm fatigue is to blame for the excessive number of warnings that nurses must deal with every day.

According to Funk et al.[17] some nurses may view monitor alarms as a way to keep their patients safe, while others may find them annoying. This finding is in line with our findings, which show that critical care nurses believe frequent false alarms to be the most significant alarm-related problem, even though they also believe alarms are crucial for clinical outcomes. Also, our findings concurred with those of Steege and Pinekenstein,[18] who claimed that the rise in false alarms generated a background noise that nurses ignored and that later turned into an unwelcome alarm racket.

Additionally, Cho et al.[19] previously published findings that were comparable to ours, revealing that critical care nurses were worn out as a result of the excessive frequency of alerts that contributed to alarm indifference. According to Graham and Cvach,[20] there are now up to 171 alerts per managed bed every day. Furthermore, our findings concur with those of Casey et al.,[21] who found that isolated ICU nurses believed that alerts should reflect alarm priority and importance.

The qualitative findings of the current study show that the healthcare team working in the unit typically

relies on nurses only to respond to alarms, which increases workload and workplace stress. This is in line with the findings of Ruppel et al.[9] who discovered that nurses specifically indicated that other nurses could be relied upon to assist with alarm adjustment. They did confirm, however, that doctors and other staff regularly ignored warnings and relied on the nurses to determine if an alarm was required. In that regard, Cosper et al.[22] found that interprofessional collaboration is necessary in ICUs to achieve successful customization of clinical alarms without alarm fatigue by the nursing staff.

According to the findings of our study, understaffing and the high patient-to-nurse ratio have made critical care nurses more stressed and overworked, which has occasionally made them hesitant to put other patient care responsibilities ahead of customizing clinical alerts. This is in line with Ruppel et al.'s[9] findings, which showed that critical care nurses indicated that the shortage of nurses in ICUs resulted in a backlog of work for nurses, which in turn resulted in irregular priority of alarm customization.

The results of this study also showed that extrinsic and intrinsic factors have predominated as motivating subthemes, which influence critical care nurses' customization practices for clinical alarms. Novice nurses felt more motivated to attend to alarms, and nurse leaders have been portrayed as an external force to motivate nurses to attend to clinical alarms. This is in line with a study by Ergezen and Kol,[23] which assessed nurses' reactions to monitor alarms in an ICU. The study found that nurse practitioners in intensive care settings have a variety of motivational elements that they might use to tailor clinical alerts. Many nurse practitioners were urged to adjust alarms by other staff of the healthcare team, as well as by peers, patients, and family members or visitors, or by the critical care unit's generally quiet environment. Other nurses tended to be internally motivated to personalize, either by a personal ideology of alarm control or apprehension.[24]

The phenomenology of this study also revealed that the nurses' inability to use the monitors and alarm devices was due to technological and clinical barriers, which had an impact on their inadequate response to clinical alerts and inappropriate customization. This is in line with Gazarian's[25] findings, which showed that after providing care for a patient for a longer period, the critical care nurses felt more at ease in handling the clinical instruments and beeping alarms attached to the patient.

5. Conclusions

The idea of alarm weariness has important ramifications for patient welfare, with the worst-case scenario resulting in the patient's death or significant harm. The excessively widespread nuisance alarms and insufficient personnel, which lead to misidentification of the crucial ones and endanger patient safety, are highlighted by this study. The results of this study showed that nurses have a favorable opinion of the value of alarms, but qualitative investigation of the experiences showed that customization has been severely hampered and challenged, because the healthcare team relies on the nurses to handle such tasks on their own and because there is a shortage of staff and technical training at the beginning of the placement. The study also emphasized the nurses' efforts in identifying and customizing alerts by using curiosity and deeply understanding patient cases to personalize alarm customization. Therefore, if the situation that critical care nurses are working under concerning the alarm overload added to the stress of the tasks is not effectively addressed, it could significantly influence their retention, the quality of their work, and further patient safety.

Limitations

This study's shortcomings include the following: (1) much more medical equipment that is used in patient care also generates alarms, which should be carefully reviewed because they may potentially contribute to alarm fatigue and (2) in this study, only monitor alarms were studied. Numerous additional medical equipment that produce alerts in the patient-care setting can potentially contribute to alarm fatigue and should be subjected to the same level of scrutiny.

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Ethical approval

This study was approved by the ethics committee of the Lebanese American University's institutional review board (IRB) (Approval No.: LAUMCRH.KD1.2/Apr/2020).

Conflicts of interest

All contributing authors declare no conflicts of interest.

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