Improving Alarm Response in ICU/CCU

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Abstract—Clinical alarm plays a critical role to alert clinician to situations that require urgent response. However, alarms are often ignored or switched off. The objectives of the study are to identify how clinicians responded to user response, propose response time and recommend improvements to the clinical alarm performance. A focus group was commissioned to identify the high and medium risk based alarm conditions and propose appropriate response time. A survey was carried out in Malaysia with 324 clinicians, 279 (86.1%) were registered nurses and medical assistants (MA) and 45 (13.9%) were medical doctors. The findings show that 16.0% of the respondents switched off the alarm, 20.4% silenced the alarm, 14.5% delayed to respond and 20% ignored the alarm. The findings indicate 78.1% of the respondent recommended less than 10 sec for ‘immediate respond’ for high risk alarm, 72.5% recommended less than 60 sec for ‘prompt respond’ for medium risk alarms but 49% recommended that delayed respond for low risk alarm should not be specified. This will then reduce the number of alarms and workload in ICU/CCU. The key recommendation that has been proposed to improve clinical alarm performance is to ensure the alarm signal to indicate urgency to respond. The incorporation of the response time based on risk in the design of alarm, to indicate urgency to respond in auditory alarm signal can improve user response and patient safety.

Keywords—Clinical alarm system, alarm response, patient safety

I. INTRODUCTION

With the advancement of healthcare technology, almost all medical devices in intensive care and critical care units (ICU/CCU) are incorporated with clinical alarms. Clinical alarms play a critical role as a monitoring device to assist and alert clinician to situations that require urgent response especially in ICU [1]. Immediate response to alarm is crucial as it indicates potentially life threatening complication and any delayed response leads to compromising of patient safety with potentially serious adverse consequence [2]. Numerous studies on clinical alarm systems indicate dissatisfaction among the clinicians with the clinical alarm systems [3][4][5][7][8]. These studies indicate that problems associated with clinical alarm system include too many alarms, confusing alarms, difficulty in identifying the source of an audible alarm, unnecessarily loud and distracting alarms, difficult to differentiate criticality amongst alarms and high incidence of false alarm conditions. Edworthy et al. and Hass et al. identified the five critical problems with auditory alarms in ICU and Operation Room (OR), which are acoustic similarity of alarms, too many alarms, irritating alarms, inappropriately risk mapped alarms and false alarms [10][5]. These problems are further aggravated with no standardisation in clinical alarm design, alarm signals which do not relate to patient conditions and alarm signal which do not indicate urgency [11]. These problems have led to loss of confidence among the clinicians in the alarm systems causing poor user response, alarm fatigue, ignoring and switching off the alarm [12]. Cvach in her review further highlighted that the problem of alarm desensitization is also related to high false alarm rate, poor positive predictive value and too many medical devices in hospitals today [34]. Cvach et al. also reported in another study that alarm fatigue causes nurses to desensitize alarm signals which presents potential harm to patient safety [17]. Alarm fatigue has been defined as the desensitization of a clinician to an alarm stimulus that results from sensory overload causing the response of an alarm to be delayed or missed [9]. Tanner in his article reinforced this problem by relating alarm fatigue in nurses likewise becoming anesthetized to alarm sounds as a result of excessive auditory exposure resulting in slower response time of a clinician [10]. Further, Keller and Logan indicated that alarm fatigue occurs when caregivers become overwhelmed with the large number of clinical alarms such that critical or significant events can be missed or ignored [12][13]. Whereas Wiklind and Kendler identified that...
clinicians may ignore alarms because of frequent occurrence of false auditory alarm limiting the value of the information emitted to a caregiver in a clinical situation leading to alarm fatigue [14]. These issues of failure to respond are major concern especially in ICU/CCU where the problem of not responding or delayed response can prove to be fatal to patients. This paper presents the outcome of the focus group discussion on the user response in ICU/CCU. Further surveys were conducted among the ICU/CCU clinicians to study the user response, propose response time and recommendations to improve user response.

A. User environment

User environments such as ICU/CCU can have major impacts on device use and use-related hazards such as alarm hazard. The environment in ICU/CCU causes mental workload on users to exceed their abilities to respond effectively and timely to alarms. There is physical workload associated with medical device that adds to the stress experienced by the user. Under high stress levels in ICU/CCU, the clinicians will be distracted and will have less time to make decisions. The ICU/CCU environments can limit the effectiveness of visual and auditory displays which will lead to clinicians being unable to understand critically important information on the use of the device. This error could lead to difficulty to notice alarms if they are not sufficiently loud or distinctive or the user fails to notice alarms or to make important distinctions among different alarm sources. R. D. Patterson et al. highlighted that in ICU/CCU, the patient safety is crucial but when workload is high, the alarm signals can become a distraction or a nuisance [15]. In this high workload and high pressure situations, sensitivity to human factor increases affecting the cognitive and perceptual ability of the users [15]. Burt et al. showed that perception of urgency of alarms is greatly impaired under high workload [16]. A. Guillaume et al. further highlighted that acoustical properties are less effective in stimulating perceived urgency under high workload such as ICU/CCU [19]. These increase the risk of user errors or incidents which could lead to serious complication or fatality [2][19]. Poor performance of the alarm system will result in poor patient care and patient not receiving appropriate care, which may also result in missing “true alarms” [3][18]. All these problems lead toward non-performance of the alarm system and compromises patient safety with potentially serious adverse consequence [2].

B. Alarms and adverse events

The MAUDE database in United States houses medical device reports submitted to the Food Drug Agency (FDA) by mandatory reporters such as manufacturers, importers and device user facilities and voluntary reporters such as health care professionals, patients and consumers [35]. The alarm system based on adverse events reported in the FDA-MAUDE database were reviewed over the period of 2002-2004 with search term “alarm” and the event “death” and it reported 237 incidents [36]. This was further reviewed in a report by American College of Clinical Engineering (ACCE) Healthcare Technology Foundation which indicated that 52.8% of the incidents were due to operator or users [37]. In 2004, this number increased to 449 according to US FDA’s Maude database [36]. From 2005 through 2008, FDA received 566 reports of patient deaths related to the alarms on monitoring devices. Recent reports from MAUDE from 1/12/2004 to 31/12/2014 indicate a total of 50 deaths and 844 injuries were reported due to alarm system [36]. From these adverse event reports it can be concluded that users are one of the main cause of these alarm incidents. As such it is timely to identify the alarm problems associated with user response, rectify and propose means to improve effectiveness of the alarm performance in ICU/CCU. This improvement in user response should take into account human factor consideration, the psychophysical tools and mental representation of the response sequence in alarm design [38].

C. Objective

The objectives of the study are to identify how clinicians responded to alarms, propose response time and recommend improvements to the clinical alarm performance

D. Scope

This study was limited to clinicians working in ICU/CCU in public and private hospitals in Malaysia. The participants were doctors, nurses and medical assistants (MA).

II. METHODOLOGY OF STUDY

A. Focus Group

A focus group is a group of individuals selected and assembled by researchers to discuss and comment on, from personal experience, the topic that is the subject of the research [39]. Focus groups can be used at the preliminary or exploratory stages of a study, during a study, perhaps to evaluate or develop a particular programme of activities or after a programme has been completed, to assess its impact or to generate further avenues of research [40][41][42]. In this research, the focus group was selected among the ICU/CCU clinicians comprising of consultants, specialist, doctors, tutors and senior nurses to deliberate on the challenges of clinical alarm system in ICU/CCU.

The discussion was designed to gather information from the respondents regarding the following outcomes: i) the respondent’s reaction or responses when an alarm triggers in ICU/CCU ii) the response time to represent the ‘immediate’, or ‘prompt’ and delayed response based on IEC IEC 60601-1-8:2006 recommendations [20].
These levels of urgency were graded to indicate different situations such as less urgent for delayed response time, urgent for prompt response time and critical for immediate response time. For high risk patient conditions, the following conditions were discussed in the focus group to identify response time:

- Asystole
- Ventricular fibrillation
- Failure of a cardiac support device (intra-aortic balloon pump, cardiopulmonary bypass machine)
- Sustained high airway pressure
- Extreme hypoxemia

The medium risk physiological conditions that requires prompt response:

- Cardiac arrhythmias associated with hypotension
- Low blood pressure, Hypotension
- Apnea (unless prolonged or associated with extreme hypoxia)
- Mild hypoxemia
- Failure of an infusion pump for maintenance of vasopressor agents

iii) list of improvement needed in a physiological patient monitor.

B. Survey

The survey was conducted throughout Malaysia and the questionnaires were distributed to public and private hospitals. A total of 10 hospitals participated in this survey. It was conducted among clinical staff in the ICU. This survey was conducted to study the perception and response of the clinical staff towards the alarm system. The survey was to undertake a comparative study of responses of two groups of users or clinicians, group 1 consists of doctors and group 2 consists of nurses and medical assistants (MA). The objectives of the survey are to identify how clinicians responded to clinical alarm, recommendation to alarm response time for physiological conditions that needed ‘immediate’, ‘prompt’ and ‘delayed’ response and user recommendations to improve alarm system design for physiological patient monitor.

A questionnaire was developed for the purpose of this survey based on the outcome of the focus group discussion. There were four sections in the questionnaire, focusing on obtaining information regarding the clinical alarm systems and the associated problems in the ICU/CCU. The questionnaire is attached in Annex 1. The first part, Part A, requested demographic information from the respondents as to the length of services in ICU/CCU, designation and were categorised into age groups below 25, 25 to 35, 35 to 45 and above 45. Part B of the survey was to identify how frequently the respondents reacted or responded when an alarm triggers in ICU/CCU. Part C on preferred response time for immediate, prompt and delayed response as specified in IEC60601-1-8:2006 [20].

In the questionnaire, three sets of response time had been proposed for immediate response that are, less than 10 seconds, 10-20 seconds and less than 30 seconds whereas for prompt response, less than 1 minute, 1-5 minutes and less than 15 minutes. Further the improvements proposed by the focus group were listed in the questionnaire for the respondents to identify the key areas of improvement needed in a physiological patient monitor. Mann-Whitney test was carried out using IBM SPSS STATISTICS 21. Z-tests and charts were created using Microsoft Excel 2007.

III. RESULTS

A. Focus Group Findings

A total of 9 clinicians working in the ICU/CCU participated in the focus group(FG) discussion, one consultant, one specialist, 2 doctors, three senior nurses and a nursing tutors

Outcome 1: The respondent’s reaction or response when an alarm triggers in ICU/CCU.

In general, the respondents agreed that clinical alarms monitors and alerts clinician to situations and conditions that have exceeded normal physiological limit. They stressed that in ICU/CCU the alarms play an extremely important role as a life saving device to monitor the physiological condition of critically ill patient that require urgent response. They indicated that there were numerous problems associated with clinical alarm system such as too many alarms, confusing alarms, difficulty in identifying the source of an audible alarm, unnecessarily loud and distracting alarms, difficult to differentiate criticality amongst alarms and high incidence of false alarm conditions. The clinicians agreed that they responded immediately to alarm signal most of the time however they too delayed the response, ignored, switched off and silenced the alarms.

Outcome 2: The response time to represent the ‘immediate’, or ‘prompt’ and delayed response based on IEC 60601-1-8:2006 recommendations [20].

The FG agreed that immediate response to alarm is crucial. Any delay in responding could lead to death and potentially life threatening complication. Therefore delayed response compromises patient safety with potentially serious adverse consequence.

However the FG also indicated that alarm signal should be based on the risk associated to the patient’s physiological condition. The alarm signal should not only alert the clinicians but also need to inform them the conditions of the patient. The information with regards to response time for these physiological conditions which triggered the alarm need to be embedded in the signal. As such they
Section B

Survey Findings

Table 1 presents the demographic profile of the respondents. The respondents comprised of 279 (86%) nurses and 45 (14%) doctors. Almost half (52.0%) of the nurses were 25 to 35 years old and only 12 (4.4%) were above 45 years old. Similarly, majority (68.9%) of doctors were 25 to 35 years old and only 4 (8.8%) were more than 45 years old.

In Section B of the survey, we investigated problems associated with alarm system in ICU/CCU. The respondent needed to tick one of the options below:
1 = Strongly Disagree
2 = Disagree
3 = Agree
4 = Strongly agree

The responses were then recoded as 1 (Agree or Strongly Agree) if the value chosen is 3 or 4 and 0 (Strongly Disagree or Disagree) if the number chosen is 1 or 2. The z-test for two proportions was used to test if there is any significant difference in the proportions of doctors and proportion of nurses who agree or strongly agree regarding problems associated with the alarm system. Results summarised in Table 2 shows that a high proportion of nurses agreed that there are too many alarms (72%) and similar device from different brand or model do not have similar alarm sounds (73%). Meanwhile, 65% of doctors agreed that similar device from different brand or model do not have similar alarm sounds as the main problem associated with alarm system in ICU/CCU.

There are significant differences of agreement for items ‘Too many alarms’, ‘Alarms are too loud’, ‘Alarms not audible’ and ‘Alarms are nuisance’ in ICU/CCU (B1, B2, B3 and B5) with a higher proportion of nurses who agreed on these four issues.

In Section D, we investigated user response when an alarm is triggered in ICU/CCU. The respondent needed to tick one of the options below:
1 = None
2 = Sometimes
3 = Most of the time
4 = All the time

The responses were then recoded as 1 (Most or all the time) if the value chosen is 3 or 4 and 0 (None or sometimes) if the number chosen is 1 or 2. The z-test for two proportions was again used to test if there is any significant difference in the proportions of doctors and proportion of nurses who responded most or all the time when an alarm is triggered. The results are summarized in Table 3 shows how the clinicians reacted or responded when an alarm is triggered in ICU/CCU. A total of 91% of the respondents agreed that they responded immediately when an alarm was triggered.

The findings indicate 17% of the respondent switched off the alarm, higher percentage of nurses (18%) to doctors (9%) switched off the alarm. The findings indicate 21% of the respondent silenced the audio of the alarm. It also indicates higher percentage of nurses (22%) compared to doctors (16%) silenced the audio of the alarm. A total of 6% of the respondents agreed that they failed to respond when an alarm was triggered. Among the respondents, 7% of the nurses and 4% of the doctors agreed that they ignored (failed to respond) when an alarm was triggered. There is no

Outcome 3: list of improvement needed in a physiological patient monitor

The FG recommended the following improvements to physiological patient monitor:

- Alarm sound indicates urgency to respond to critical alarm;
- Audio sound to indicate severity of the patient condition Medium(M) and High(H) Risk;
- Alarms sound designed based on human factor;
- Integrate action plan with each alarm condition Hand M;
- Interactive and guided alarm system to set limit based on physiological condition of patient;
- Alarm sound level: automatically adjust to the surrounding sound level;
- Different manufacture of same device to have similar alarm sounds;
- Visual light indicator to indicate that the device has problem(faulty) until rectified (no reset allowed);
- When there are more than 2 conditions, the highest risk condition monitored by patient monitor to trigger alarm sound;
- Biometric of user (clinician) to activate or deactivate alarm or make any changes in alarm limit setting; and
- Integrate all alarm attached to patient, one patient one audio alarm

B. Survey Findings

A total of 324 respondents, 45 doctors and 279 nurses/MAs participated in this survey.
significant difference in alarm response between doctors and nurses.

In Section E, we investigate recommendations for alarm response time. The respondent needed to tick one of the options below:
1= Strongly Disagree
2= Disagree
3= Agree
4= Strongly agree

The responses were then recoded as 1 (Agree or Strongly Agree) if the value chosen is 3 or 4 and 0 (Strongly Disagree or Disagree) if the number chosen is 1 or 2. The z-test for two proportions was used to test if there is any significant difference in the proportions of doctors and proportion of nurses who agree or strongly agree regarding recommendations for alarm system response time. The results are summarized in Table 4.

As shown in Table 4, 81% of the respondents recommended alarm response time for immediate response (high risk conditions) should be less than 10 sec. A total of 81% of the respondents recommended alarm response time for prompt response (medium risk conditions) should be less than 1min (60sec). A total of 49% of the respondents recommended that delayed response time for low risk incidents should not be specified.

In Section F, we investigated with regards to recommendations to improve alarm system design for the physiological patient monitor. The respondent needed to tick one of the options below:
1= Strongly Disagree
2= Disagree
3= Agree
4= Strongly agree

The responses were then recoded as 1 (Agree or Strongly Agree) if the value chosen is 3 or 4 and 0 (Strongly Disagree or Disagree) if the number chosen is 1 or 2. The z-test for two proportions was used to test if there is any significant difference in the proportions of doctors and proportion of nurses who agree or strongly agree regarding recommendations to improve alarm system design for the physiological patient monitor. The summary of the user recommendations to improve alarm system design for physiological patient monitor are provided in Table 5. It is noted that 92.0% of the respondents recommended that alarm sound should indicate urgency to respond to the critical alarm. Both the respondents, 91.0% of the nurses/MA and 97.8% of the doctors agreed strongly that the alarm sound should indicate urgency to respond to the critical alarm. It is to be noted that 86.7% of the respondents recommended an interactive and guided alarm system to set limits based on physiological condition of patient. Whereas 86.1% recommended three (3) types of alarm sounds: low (L), medium (M) and high (H) risk in the physiological patient monitor. It is to be noted that 82.1% of the respondents recommended that the alarms’ sound should be designed based on human factors.

IV. DISCUSSION

A clinical alarm system assists clinicians as a surveillance tool and enhances performance to monitor, warn and alert them of changes in the physiological condition of the patient. The focus group findings indicated that the clinicians are aware of the intended use of the alarm system to enhance patient safety and the key roles in monitoring critically ill patient in ICU/CCU. As such, most of the time the clinician responded immediately to alarm signals. However, the findings also indicated that the clinicians too delayed to respond to alarms, ignored, switched off and silenced the alarm signal. This issue of failure ‘to respond’ needs to be considered seriously and the main reasons need to be identified and addressed. In critical areas such as the ICU/CCU, the problem of clinicians not responding to the alarm system could prove fatal to the patient. The focus group had raised concerns on these issues and identified that too many alarm problems has led to alarm fatigue and lack of confidence in the alarm systems amongst the clinician. The focus group had raised dissatisfaction on clinical alarm systems and issues of too many alarm problems which had been raised in numerous studies with the clinical alarm systems [3][4][5][7][8]. J McIntyre et al. had also indicated that these problems had led to lack of confidence in the alarm systems and the clinician to disregard, ignore or refuse to use alarms [26]. National survey conducted by the Healthcare Technology Foundation (HTF) on clinical alarm issues also indicated the problems of alarm system which cause users to ignore alarms [37]. To overcome these problems, especially on user response, it is proposed in this research that the alarm signals are designed based on risk and this information be embedded in the alarm sounds. This is to ensure the alarm signals can be easily identified and differentiated according to the risk of the patient’s physiological condition. Patterson et al. graded this risk into three levels low, medium and high to ensure alarms are responded in a timely manner [27]. Whereas Edworthy et al. who investigated the impact of urgency on alarm response and indicated that urgency mapping increases the information of the level of priority, situation and response time in the alarm system [29][40]. This study further explores into urgency mapping by identifying appropriate response time to map this urgency to respond in the alarm signal.

This focus group proposed to adopt graded response time to represent three levels of urgency as recommended by the international standard, IEC 60601-1-8:2006 and Patterson et al. However, the focus group proposed that alarms should only be triggered for high and medium risk incidents to reduce the number of alarms and alarm fatigue in ICU/CCU.

The focus group also explored improvements to alarm problem concerning user response associated to physiological patient monitor. The recommendations are as follows:
• Alarm sound indicates urgency to response to critical alarm
• Audio sound to indicate severity of the patient condition
  Medium (M) and High (H) Risk
• Alarms sound designed based on human factor
• Interactive and guided alarm system to set limit based on physiological condition of patient.

These recommendations indicated that the alarm system need to be designed based on human factor engineering principles to address human limitations by providing relevant and timely information to users. These proposed response time by the FG were used in the survey to investigate the acceptance among the clinicians in the healthcare institution in Malaysia. The survey findings indicated that clinicians react and respond differently to different types of alarm. Their responses to alarm signal also included immediate response, delayed response, switch off, silenced the alarm and ignore the alarm signal. Similar responses towards alarm signal also indicated that the respondents of the survey perceived the present clinical alarm system to have too many alarm problems, unreliable and lack confidence in the alarm system. Block et al. in their study indicated that when alarm systems are unreliable, they tend to be ignored [21].

In this survey, a total of 17% of the respondent switched off the alarm, higher percentage of nurses (18%) to doctors (9%) switched off the alarm. The findings indicated 14.5% of the respondent delayed the respond to alarm signal. Whereas 21% of the respondent silenced the audio of the alarm. It also indicates higher percentage of nurses (22%) compared to doctors (16%) silenced the audio of the alarm. A total of 6% of the respondents agreed that they ignored the alarm. Among the respondents, 7% of the nurses or MA and 4% of the doctors have agreed that they ignored (failed to respond) when an alarm was triggered. These findings indicate that there is no significant difference between the doctors and nurse/MA response to alarm signal. This delayed or no response compromises patient safety with critical conditions undetected and leads towards occurrence of adverse events [41]. In addressing this shortcomings of the alarm system as to when to respond, information on urgency to respond based on risk of the patient’s physiological condition needed to be embedded in the alarm signal.

In this survey, the respondents were requested to identify the preferred alarm response time for immediate, prompt and delayed respond. A total of 81% of the respondents agreed that the recommended alarm respond time for immediate response (high risk conditions) should be less than 10 seconds. Whereas a total of 81% of the respondents agreed that the recommended alarm respond time for prompt response (medium risk conditions) should be less than 1min (60sec). Only a total of 49% of the respondents agreed that delayed respond time for low risk incidents should not be specified as proposed by the focus group. Though FG do not want the low risk to trigger alarm in ICU but 51% of the respondent in the survey thinks otherwise. Since the FG recommended that the low risk alarm conditions should not trigger alarm and 49% of the respondents concur with them, therefore it is proposed as a compromise that only visual alarm and not auditory alarm to be triggered for low risk conditions.

In the above premises, it is proposed that the response time which indicates the urgency to respond can be embedded in the alarm signal. These proposed times will guide the clinicians to respond accordingly.

The concept of ‘urgency mapping’ was introduced by Edworthy et al. to improve the response of the users [28][29]. Urgency mapping is defined as matching between the perceived urgency of the warning and urgency of alarm conditions [42]. In another study, E. Hellier et al. proposed that urgency mapping be embedded in the alarm design [30]. Early studies by Edworthy et al. showed that urgency of auditory alarms can be achieved by changing the acoustic parameters of the auditory signals [33]. Hellier et al. further detailed the relationship between objective parameters and subjective parameters that can be incorporated in the design of auditory warnings to facilitate urgency mapping [32]. Urgency mapping allows warnings to be mapped to situations that trigger appropriate user response. Further the perceived urgency in alarm system designs can be ranked to indicate the level of urgency associated with different alarms [32]. The level of urgency can be mapped to specific alarm sound [32]. Using psychophysics principles, Edworthy et al. and Hellier et al. defined that the acoustic properties induced different degrees of urgency perception [42]. Under high workload such as ICU/CCU, mental representation and psychophysical tools should also be taken into consideration in alarm design [19]. To further improve this concept, the proposed response time of the survey findings can be embedded in the alarm signal to indicate the actual respond time, visually or through audio representation. This will improve the alarm response accordingly.

In line with these previous studies, the findings in Table V indicate 92.0% of the respondents recommended for physiological monitor that alarm sound should indicate urgency to respond to the critical alarm. These findings also indicated that there are no significant difference between the doctors and nurse/MA recommendations to improve alarm response.

V. CONCLUSION

From the findings of this study, it can be concluded that the various alarm responses of the clinicians are immediate response, delayed response and no response that is by switching off, silencing and also by ignoring the alarm.

Further it can be established that by adopting not to respond to low risk alarm conditions, the number of alarm and workload in ICU/CCU can be reduced significantly thereby reducing the chances of occurrence of alarm fatigue among the clinicians. The key recommendation that has
TABLE I: DEMOGRAPHY OF RESPONDENTS

<table>
<thead>
<tr>
<th>Variable</th>
<th>Gender</th>
<th>Male</th>
<th>Female</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td></td>
<td>21 (46.7%)</td>
<td>24 (53.3%)</td>
<td></td>
</tr>
<tr>
<td>Nurse/MA</td>
<td></td>
<td>25 (9.4%)</td>
<td>240 (90.6%)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Position</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td>1 below 25</td>
<td>66 (24.2%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>25-35</td>
<td>142 (52.0%)</td>
<td>31 (68.9%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>36-45</td>
<td>53 (19.4%)</td>
<td>10 (22.2%)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Above 45</td>
<td>12 (4.4%)</td>
<td>4 (8.8%)</td>
</tr>
</tbody>
</table>

TABLE II: PROBLEMS ASSOCIATED WITH ALARM SYSTEM IN ICU/CCU

<table>
<thead>
<tr>
<th>Item</th>
<th>Overall</th>
<th>Doctors</th>
<th>Nurses</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>211</td>
<td>66</td>
<td>11</td>
</tr>
<tr>
<td>B2</td>
<td>155</td>
<td>48</td>
<td>11</td>
</tr>
<tr>
<td>B3</td>
<td>135</td>
<td>42</td>
<td>22</td>
</tr>
<tr>
<td>B4</td>
<td>106</td>
<td>34</td>
<td>7</td>
</tr>
<tr>
<td>B5</td>
<td>229</td>
<td>72</td>
<td>28</td>
</tr>
<tr>
<td>B6</td>
<td>177</td>
<td>57</td>
<td>21</td>
</tr>
<tr>
<td>B7</td>
<td>163</td>
<td>52</td>
<td>17</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>Too many alarms.</td>
</tr>
<tr>
<td>B2</td>
<td>Alarms are too loud.</td>
</tr>
<tr>
<td>B3</td>
<td>Alarms not audible.</td>
</tr>
<tr>
<td>B4</td>
<td>Alarms sound are annoying.</td>
</tr>
<tr>
<td>B5</td>
<td>Alarms are nuisance in ICU/CCU</td>
</tr>
<tr>
<td>B6</td>
<td>False positive alarms are rampant/frequent.</td>
</tr>
<tr>
<td>B7</td>
<td>False negative alarms are rampant/frequent.</td>
</tr>
</tbody>
</table>

Notes: f=overall number of responses for 3 (Agree) and 4 (Strongly Agree)

TABLE III: AGREEMENT ON HOW USERS REACT OR RESPOND WHEN ALARM IS TRIGGERED

<table>
<thead>
<tr>
<th>Question</th>
<th>Doctors</th>
<th>Nurses</th>
<th>Overall</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Immediate</td>
<td>41 (91.1%)</td>
<td>245 (87.8%)</td>
<td>286 (88.3%)</td>
<td>0.524</td>
</tr>
<tr>
<td>Switch off alarm</td>
<td>4 (8.9%)</td>
<td>48 (17.2%)</td>
<td>52 (16.0%)</td>
<td>0.158</td>
</tr>
<tr>
<td>Silence the audio alarm</td>
<td>7 (15.6%)</td>
<td>59 (21.1%)</td>
<td>66 (20.4%)</td>
<td>0.387</td>
</tr>
<tr>
<td>Ignore the alarm</td>
<td>2 (4.4%)</td>
<td>18 (6.5%)</td>
<td>20 (6.2%)</td>
<td>0.604</td>
</tr>
</tbody>
</table>

TABLE IV: AGREEMENT TO THE RECOMMENDED ALARM SIGNAL RESPONSE TIME

<table>
<thead>
<tr>
<th>Response/Time (sec)</th>
<th>Overall</th>
<th>Doctors</th>
<th>Nurses</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Immediate&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;10</td>
<td>253</td>
<td>81</td>
<td>39</td>
</tr>
<tr>
<td>10-20</td>
<td>131</td>
<td>57</td>
<td>19</td>
</tr>
<tr>
<td>&lt;30</td>
<td>68</td>
<td>30</td>
<td>7</td>
</tr>
<tr>
<td>&quot;Prompt&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;60</td>
<td>235</td>
<td>81</td>
<td>38</td>
</tr>
<tr>
<td>60-300</td>
<td>144</td>
<td>62</td>
<td>20</td>
</tr>
<tr>
<td>&lt;900</td>
<td>55</td>
<td>25</td>
<td>2</td>
</tr>
<tr>
<td>&quot;Delayed&quot;</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>40</td>
<td>140</td>
<td>49</td>
<td>16</td>
</tr>
</tbody>
</table>

*p<0.05; **p<0.01; f=frequency
been proposed to improve clinical alarm performance is to ensure the alarm signal to indicate urgency to respond. It can be concluded that incorporation of the response time based on risk in the design of alarm, to indicate urgency to respond in auditory alarm signal can improve user response and patient safety.

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