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Reaction time of a health care team to monitoring alarms in the intensive care unit: implications for the safety of seriously ill patients

Tempo estímulo-resposta da equipe de saúde aos alarmes de monitorização na terapia intensiva: implicações para a segurança do paciente grave

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ABSTRACT

Objective: To define the characteristics and measure the reaction time of a health care team monitoring alarms in the intensive care unit.

Methods: A quantitative, observational, and descriptive study developed at the coronary care unit of a cardiology public hospital in Rio de Janeiro state (RJ). Data were obtained from the information collected on the patients, the monitoring used, and the measurement of the team's reaction time to the alarms of multi-parameter monitors during a non-participatory field observation.

Results: Eighty-eight patients were followed (49 during the day shift and 39 during the night shift). During the 40 hours of observation (20 hours during the day shift and 20 hours during the night shift), the total number of monitoring alarms was 227, with 106 alarms during the day shift and 121 during the night shift, an average of 5.7 alarms/hour. In total, 145 alarms unanswered by the team were observed, with 68 occurring during the day shift (64.15%) and 77 during the night shift (63.64%). This study demonstrated that the reaction time was longer than 10 minutes in more than 60% of the alarms, which were considered as unanswered alarms. The median reaction time of the answered alarms was 4 minutes and 54 seconds during the day shift and 4 minutes and 55 seconds during the night shift. The respiration monitoring was activated in only nine patients (23.07%) during the night shift. Regarding the alarm quality of these variables, the arrhythmia alarm was qualified in only 10 (20.40%) of the day-shift patients and the respiration alarm in four night-shift patients (44.44%).

Conclusion: The programming and configuration of the physiological variables monitored and the parameters of alarms in the intensive care unit were inadequate; there was a delay and lack of response to the alarms, suggesting that relevant alarms may have been ignored by the health care team, thus compromising the patient safety.

Keywords: Intensive care/standards; Monitoring, physiologic/instrumentation; Clinical alarms; Patient safety; Equipament failure; Intensive care units

INTRODUCTION

The constant incorporation of invasive and noninvasive monitoring and advanced life support technologies at the bedside has led to a large number of alarm sounds triggered by these devices in intensive care units, a fact that has been an issue widely discussed and internationally studied for over a decade, considering its consequences for patient safety.[1-13]

The main evidence from these studies demonstrates problems with alarm systems, monitoring equipment, and human resources in intensive care units;[1-13] in addition, "alarm fatigue" is discussed.[1-5]

Alarm fatigue occurs when a large number of alarms mask those that are clinically significant, leading to alarms with clinical relevance being ignored, silenced, or disabled by the health care team. The elevated number of alarms causes sensory overload and desensitization of the health care team and reduces their alertness and confidence in the sense of urgency of the alarms, which can cause the team's lack of response. When clinically relevant alarm signals are underestimated, the result might be a critical condition for the patient, compromising his/her safety.[1-5]

According to recent data from the Emergency Care Research Institute, alarm hazards were number one on the list of the top ten health technology hazards in 2012 and 2013 and are among the top ten for 2014, given the frequent reports of alarm-related incidents involving patients in hospitals in the United States.[14-16]

Between 2005 and 2008, the Food and Drug Administration (FDA) and the Manufacturer and User Facility Device Experience (MAUDE) received 566 reports of patient deaths related to alarms on monitoring devices in hospitals in the United States. Between March and June 2010, the MAUDE recorded more than 73 deaths related to alarms, with 33 attributed to multi-parameter monitors.[17] Due to these concerning findings, studies related to alarm fatigue are crucial; when the phenomenon is evidenced, attention is directed to alarm-related problems, and data are provided for minimizing these problems during the intensive care unit routines.[17]

Incidents with damage involving alarms on medical equipments and patients in intensive care units led the Joint Commission to submit (as a proposal for 2014) the management of clinical alarms in hospitals with accreditation programs, aiming to improve patient safety in the use of these systems.[18]

Considering the novelty and relevance of this topic in Brazil, the goals of this study were to measure the reaction time of a health care team to alarms of multi-parameter monitors in a coronary care unit and determine their characteristics.

METHODS

A quantitative approach was used, involving a descriptive observational study developed at the Coronary Care Unit of the *Instituto Nacional de Cardiologia* (INC), located at Rio de Janeiro state (RJ, Brazil); this hospital has a functional capacity of 170 beds.

The data were obtained through observing five beds in the unit (beds 1-5), which were designated for the most severe and unstable hospitalized patients who were using hemodynamic, ventilatory, and mechanical support, configuring a convenience sample. The observation was not participatory, i.e., the researcher was not involved with the context to be observed and did not participate in the clinical activities. The study was limited to five beds in the unit in order to facilitate the reliable measurement and counting of all sounded alarms.

A nurse (author of the study), who was not part of the staff on duty, remained between the beds, moving silently when necessary and carefully observing the audible and visual signs of the monitors, considering that the volume of the alarm sounds were eventually set to minimal or inaudible levels. This nurse measured the reaction time of the team and recorded the data. All professionals from the nursing team in the unit authorized the observation through the Free and Informed Consent Term (*Termo de Consentimento Livre e Esclarecido* - TCLE).

The use of vasoactive, antiarrhythmic, antihypertensive, and inotropic drips was considered hemodynamic support; the use of an intra-aortic balloon (IAB) was considered mechanical support, and the use of invasive mechanical ventilation was considered ventilatory support.

These five beds were equipped with multi-parameter monitors (Agilent® V26C/Anesthesia), which presented the following features: volume adjust from 0 to 255 dB, emission of visual signal (light) of the physiological variable in the alert mode, Portuguese language, and an alarm pause of 3 minutes. There was no central monitor in the unit. The mechanical ventilators used were SERVO-s®, and the infusion pumps were B. Braun Infusomat® Compact and Datascope 97E® Intra-Aortic Balloon pumps.

Forty hours of discontinued observation were performed on different days and times, between March and June 2012, with 20 hours of observation performed during the day shift (DS - between 7:00 am and 6:00 pm) and 20 hours during the night shift (NS - between 7:00 pm and 12:00 am). This strategy was adopted to address the variability of situations and routines in both shifts and to avoid trend bias in the sample.

Initially, for the data production, the following information about the observed patients and their monitoring at the time of observation were recorded: clinical diagnosis, therapeutic support used, monitored physiological variables (heart rate - HR, electrocardiographic tracing-arrhythmias - ECG, non-invasive arterial blood pressure - NIBP, mean invasive arterial blood pressure - IBP, respiration, oxygen saturation/pulse oximetry - SpO_2,

and pulse), qualified monitoring alarms, and their volume. Notably, there was no standardization protocol for the monitored physiological variables or for the individual alarm parameterization in this unit; their adjustment and configuration were randomly performed by the team.

Six digital timers were used to measure the reaction time of the team to monitoring alarms through the non-participatory field observation (except in situations with more severe complications). At that time, the physiological variables during the alert, the categories and conduct of the professionals who responded, and the date and time of observation were also recorded.

The reaction time was defined as the time between the triggering of the alarm sound and the arrival of the professional at the patient bedside and the alarm interruption. Alarms with a reaction time exceeding 10 minutes were recorded as unanswered/fatigued, and the worst outcome for the patient was considered (reduced survival and neurological sequelae) if the unanswered alarm indicated an absolute emergency.[19-21]

The 10-minute limit for unanswered alarms was based on the American Heart Association (AHA) guidelines regarding the resuscitation procedures because, from the pathophysiological point of view, 10 minutes after the onset of cardiopulmonary arrest (CPA) caused by the rhythms ventricular fibrillation (VF), pulseless ventricular tachycardia (PVT), pulseless electrical activity (PEA), and asystole, the triggering of inflammatory cytokines, free radicals, and cell damage occur, which can sometimes cause irreversible myocardial changes (stone heart) and severe neurological dysfunction.[22-24]

All alarms in the bed 1-5 environment that sounded from mechanical ventilators, infusion pumps, IABs, and hemodialysis (HD) pumps were counted without timing and defined as other clinical alarms of medical equipment.

For the analysis, data from the periods of observation and patients were organized on a Microsoft® Office Excel 2007 spreadsheet, processed, and analyzed using the R software version 2.15.1. A descriptive statistical analysis was performed for the study variables, showing aspects such as the mean, median, simple and absolute frequencies, and data dispersion (interquartile range - IQ).

The study met the specifications of the Resolution 196/96 and was approved by the Ethics and Research Committee (*Comitê de Ética e Pesquisa* - CEP) of the INC (CEP/INC nº 0351/11). Free and informed consent was obtained from the nursing team professionals involved in the study.

RESULTS

During the data collection period, 49 monitored patients were observed during the DS and 39 during the NS, totaling 88 patients.

In the months when the data were collected, the patients' hospitalization rate ranged from 6.8 to 11.7 days, and the average occupancy rate in the unit was 97.94%. The most frequent clinical diagnoses in the patients were acute myocardial infarction (AMI) with ST-segment elevation (25), AMI without ST-segment elevation (20), and unstable angina (10). The mean Global Registry of Acute Coronary Events (GRACE) score, which is a predictor of cardiovascular events for coronary disease (CAD) in patients in the unit during the observation period was 168, demonstrating their severity (high risk if greater than 140).[25]

The profile of the severity and complexity of the observed patients was also characterized by the use of therapeutic support; hemodynamic support was used during the DS (n=49) by 34 patients (69.38%) and during the NS (n=39) by 15 patients (38.46%). During the DS, two patients (4.08%) used mechanical support, and during the NS, eight patients (20.51%) used mechanical support. Ventilatory support was used by 37 patients (75.51%) during the DS and by 24 patients (61.54%) during the NS.

Table 1 presents the physiological variables monitored in the observed patients, the qualified alarms related to these variables, and the volume level of the alarms in the multi-parameter monitors from the DS and NS during the observation. The minimum alarm volume recorded during the DS was 15 dB (inaudible level), and the maximum alarm volume was 120 dB. During the NS, the minimum volume was 45 dB, and the maximum was 120 dB; regarding the median and IQ obtained, there was no significant variation between the services.

The total number of multi-parameter monitor alarms that sounded within the 40 hours of observation (20 hours during the DS and 20 hours during the NS) was 227 alarms (mean, 5.7 alarms/hour), with 106 alarms (mean, 5.3 alarms/hour) during the DS and 121 alarms (mean, 6.0 alarms/hour) during the NS. The monitoring alarms that sounded during the DS and NS, considering the total number of alarms triggered in the unit were, respectively: HR: 34 (32.08%) and 22 (18.18%); arrhythmia: 3 (2.83%) and 7 (5.79%); IBP 26 (24.53%) and 19 (15.70%); NIBP: 10 (9.43%) and 15 (12.40%);

Table 1 - Physiological variables monitored in the observed patients, respective qualified alarms, and alarm volume level of the multi-parameter monitors of the day shift and night shift

Physiological variables	Physiological variables monitored in the observed patients	Qualified alarms related to the monitored variables
Day shift (N=49)		
Arrhythmia/continuous ECG	49 (100)	10 (20.40)
HR	49 (100)	45 (91.83)
IBP and NIBP	49 (100)	47 (95.91)
Pulse	46 (93.87)	1 (2.17)
Respiration	30 (61.22)	18 (60.00)
SpO_2	46 (93.87)	18 (39.13)
Volume of the multi-parameter monitors alarm (dB) 75 (60-90)		
Night shift (N=39)		
Arrhythmia/continuous ECG	39 (100)	18 (46.15)
HR	39 (100)	39 (100)
IBP and NIBP	39 (100)	35 (89.74)
Pulse	38 (97.43)	0 (0.00)
Respiration	9 (23.07)	4 (44.44)
SpO_2	38 (97.43)	23 (60.52)
Volume of the multi-parameter monitors alarm (dB) 90 (60-90)		

HR - heart rate; IBP - mean invasive arterial blood pressure; NIBP - non-invasive arterial blood pressure; SpO_2 - oxygen saturation; IAB - intra-aortic balloon; IQ - interquartile range. The results are expressed as the number (%), median, and interquartile range. The percentage values of the alarms refer to the number of alerts effectively qualified in monitored patients with the parameter specified.

respiration: 16 (15.09%) and 5 (4.13%); and SpO_2: 17 (16.04%) and 53 (43.80%). Table 2 presents the total clinical alarms originating from the medical equipments that sounded during the DS and NS in the observed beds. In total, 199 other alarms coming from infusion pumps, hemodialysis devices, mechanical ventilators, and IABs were obtained during the 40 hours of observation (mean, 4.9 alarms/hour), with 124 alarms recorded during the DS (mean, 6.2 alarms/hour) and 75 alarms recorded during the NS (mean, 3.7 alarms/hour).

Table 2 - Clinical alarms of the medical equipment that sounded during the day shift and during the night shift

Shift	Multi-parameter monitor	Infusion pump	Mechanical ventilator	Hemodialysis	IAB	Total
Day	106	73	42	9	0	230
Night	121	42	24	8	1	196
Total	227	115	66	17	1	426

IAB - intra-aortic balloon.

Of the 227 monitoring alarms in total (106 during the DS and 121 during the NS), 145 unanswered/fatigued alarms were found in the unit: 68 (64.15%) during the DS and 77 (63.64%) during the NS; 82 alarms with a response: 38 (35.85%) during the DS and 44 (36.37%) during the NS. Among these alarms with a response, 31 (81.57%) during the DS were responded to by nurses, and 12 (27.27%) during the NS were responded to by nurses; six (15.78%) during the DS were responded to by nurse technicians, and 32 (72.73%) during the NS were attended by nurse technicians; one (2.63%) was attended by another professional during DS and by none during the NS. The majority of the alarms were attended by the nursing team during both the DS and the NS, as shown in figure 1.

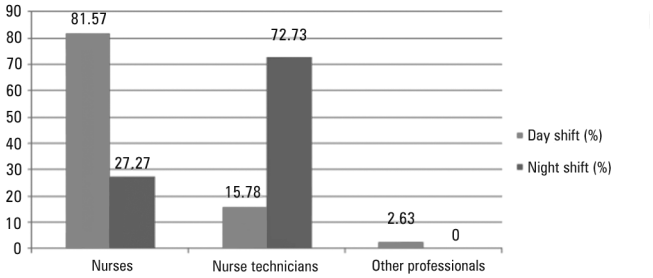

Figure 1 - Response to the monitoring alarm according to the professional team. Values are expressed as percentages. The values refer to 82 alarms with a response, with 38 (35.85%) during the day shift and 44 (36.37%) during the night shift.

The reaction time of the team to the monitoring alarms in the observed patients during the DS and NS were, respectively: 4 minutes 54 seconds (3 minutes 4 seconds - 7 minutes 28 seconds); minimum: 20 seconds, maximum: 9 minutes 55 seconds and 4 minutes 55 seconds (2 minutes 35 seconds - 7 minutes 19 seconds); minimum: 1 minute 5 seconds, maximum: 9 minutes 38 seconds.

From the 82 alarms with responses (38 alarms during the DS and 44 alarms during the NS), 43 alarms were answered within 5 minutes (20 alarms during the DS and 23 during the NS), with a minimum reaction time of 20 seconds and a maximum of 5 minutes. These 43 alarms represented 18.94% of the 227 alarms that sounded during the observed period. Figure 2 shows the approaches adopted by the team in response to the alarms. A pause in the alarm was the most common procedure performed by the team during both the DS and the NS. Electrode adjustment was the second most common procedure performed during the DS, considering that HR was the variable that more often triggered the alarms (n=34; 32.08%). Sensor replacement was the second most common procedure performed during the NS, and oxygen saturation was the variable that more often triggered the alarms (n=53; 43.80%).

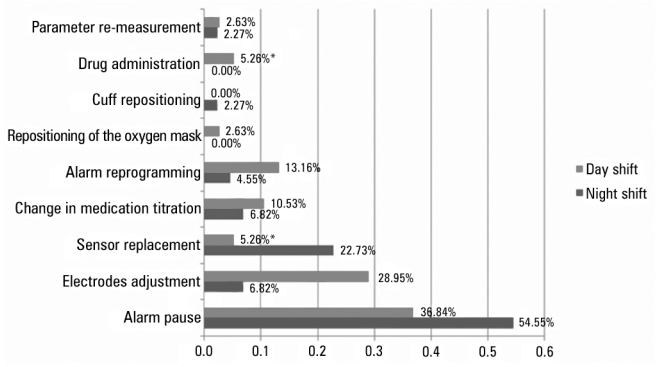

Figure 2 - Procedures performed by the nursing team in response to the monitoring alarm. Values are expressed as percentages. The values refer to 82 alarms with a response, with 38 (35.85%) during the day shift and 44 (36.37%) during the night shift. * One alarm generated two procedures.

DISCUSSION

The relevant findings of this study demonstrated that the observed patients presented a significant risk of incidents because more than 60% of the alarms were unanswered (with a reaction time longer than 10 minutes), and less than 20% of the alarms were answered within 5 minutes. If these alarms were signaling a severe arrhythmia or instability, the lack or delay in the response by the health care team to the warnings might have resulted in serious consequences for the patients' clinical conditions because clinical changes would not be have been detected, which might have prevented the performance of appropriate therapeutic procedures.[1-5,22-24] These findings were compared to those from a Canadian observational study, in which 446 monitoring alarms were recorded during 49 hours of observation; 70% of these alarms did not have an immediate response from the unit team (without measuring the reaction time).[26]

Another important finding of the current study was the elevated number of alarms recorded: during 40 hours of observation, 227 monitoring alarms (mean, 5.7 alarms/hour) and 199 alarms coming from infusion pumps, hemodialysis, mechanical ventilators, and IABs (mean, 4.9 alarms/hour) were recorded, totaling 426 alarms, an overall mean of 10.6 alarms/hour. The average monitoring alarm obtained in an observational study performed in a 12-bed intensive care unit in Germany was six alarms per hour,[2] similar to the findings from the current study. In addition to predisposing to alarm fatigue, a high number of monitoring alarms and other equipment produces a stressful environment, raises the occupational risk of the professionals, and impairs the patients' rest, which increases their hospitalization time and use of analgesics and anxiolytics.[4,17] These data also demonstrate that monitors generate more alarms compared with other medical equipment, indicating the importance of proper parameterization to patients with physiological variables and alarms, in order to avoid an increased number of alarms with no clinical relevance.[4,17]

The field observations from this study suggest that if alarms are not answered and solved, they accumulate in the environment, which makes it difficult to identify their origin. As described in the literature, alarms can sound exhaustively and, under these conditions, may be ignored when relevant, considering that complications cannot be noticed.[17,27] The health care team can reach a level of alarm fatigue in which, even consciously hearing the alarms, the professionals can "mentally turn them off" and then do not answer them - as if they were not ringing.[27] Based on these findings, the limitations of humans' ability in discriminate more than six different categories of sounds in the same environment must be considered.[11]

Regarding the results related to the selected physiological variables, respiration monitoring was activated in only nine of the 39 patients observed during the DS. Authors indicate that alarm overload can lead a team to inactivate monitoring variables, reduce alarm volumes, disable them or, inadvertently, set their parameters to improper limits for the patient needs in an attempt to reduce the number of alarms. Such modifications can cause the team not to be alerted of clinical conditions in patients who require their attention.[17,27]

Arrhythmia, respiration, oxygen saturation, and pulse (both DS and NS) alarms were found disabled, in addition to alarms set with low or inaudible volume. This finding is worrisome, considering the clinical diagnosis of the observed patients who were subject to severe arrhythmias and instability. Other studies present results similar to the current data, identifying disabled alarms, alarms with low volumes, and alarms without parameters appropriate to the patients, resulting in incidents.[6,28] According to the authors, when a patient is monitored with alarms that are disabled, have a low volume, or lack the proper parameterization for the alert, depending on his/her clinical condition, a false sense of safety is created.[17,27] Nonetheless, regarding the audibility of alarms, the team should consider the flow of people in the environment, the physical layout of the unit, the background noise, and the patients profile when they adjust the alarm volumes, thereby preventing relevant alarms going unnoticed or loud noises causing discomfort - factors related to alarm fatigue.[4,14-16,29-31]

The physiological variables (with the respective qualified alarms) that more often triggered the alarms in the unit were HR, IBP, and oxygen saturation, where the latter variable presented 53 alarms during the NS. Similar results are found in two studies conducted in intensive care units in Germany, in which the researchers discuss the high sensitivity and low specificity of alarm systems, leading to false alarms, especially in pulse oximetry.[1,2] In this context, practical evidence-based recommendations should be considered, especially those that reduce false alarms, for adoption in intensive care units to minimize alarm fatigue and ensure patient safety.[4,17,18,29-32] The fact that the team should be trained to use and handle the devices and their alarm systems should be stressed, considering that this factor is essential for good results in this process.[4,17,18,29-32] Monitoring and appropriate parameterization to the clinical needs of patients improves the response of the team and their confidence in the clinical relevance and urgency of the alerts, reducing the trivialization and familiarity with these signs. Moreover, awake hospitalized patients and professionals in the intensive care unit benefit from measures that reduce noises from false alarms and alarms without clinical significance.[4,14-17,27,29-32]

It was observed in this study that among the 82 monitoring alarms with responses, 81 were responded to by the nursing staff and only one was attended by another professional. As discussed in the literature, we demonstrated here that the nursing team is the category that most often addresses monitoring equipment and their alarm systems, which makes this category the most involved in the "alarm fatigue" phenomenon and, moreover, essential in the guarantee of patient safety. Such statements justify the importance of training these professionals to manage the alarms.[4,5,17,27]

Analyzing the results of the procedures adopted by the professionals in the answered alarm, the alarm pause was the most frequent procedure, followed by electrode adjustment and repositioning of the pulse oximetry sensor. Data from the literature show that such procedures are usually adopted by alarms that are triggered by interferences or false alarms, highlighting that the alarm pause can also demonstrate the lack of real problem evaluation by the professionals.[33] In the current study, programming, monitor adjustments, and parameter re-measurement were procedures not frequently adopted. These procedures require that the professional know how to assess the clinical condition of the patient and individually program the monitor, in addition to technical expertise to manage these equipment.[33] In the current study, the real alarms triggered by significant physiological changes promoted procedures such as a change in the titration of medication drips and administration of SOS medication. The author emphasizes that the response and outcome of the alarms expend the staff's time and may lead to interruptions and distractions from tasks, which predispose to mistakes related to the cognitive work of the professionals due to lapses in attention, as well as conflicts and stress.[34]

Thus, alarm fatigue is a multifaceted problem because it involves human factors, equipment and alarm devices, internal system in the units, and components of the workflow.[33]

The results obtained in this study reinforce evidence that the programming and configuration of physiological variables, volume, and alarm parameters of multi-parameter monitors should be incorporated into the routine of the intensive care units, considering that the critical patient depends on this technological apparatus, not only for diagnostic and therapeutic purposes but also to improve his/her safety. In addition, this practice promotes a positive development in the quality of health care provided in these units and in the teamwork process.

Among the study limitations, data collection performed at a single center over a short period of observation with a small percentage of beds observed can be highlighted. Moreover, although not noted, due to the impossibility of hiding the data collection process from the professionals, it is possible that the team changed their behaviors when they were observed.

CONCLUSION

The findings of this study demonstrate a lack or delay in the response of the team to monitor alarms, suggesting that relevant alarms might have been ignored by the heath care team, thereby compromising patient safety.

Multiple clinical alarms were observed, mainly coming from the multi-parameter monitors. The programming and configuration of physiological variables, volume, and parameters of monitoring alarms in the unit were inadequate. The majority of the alarms were responded to by the nursing team in the unit, and the alarm pause was the procedure more often adopted by the professionals.

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RESUMO

Objetivo: Definir as características e mensurar o tempo estímulo-resposta da equipe de saúde aos alarmes de monitorização na terapia intensiva.

Métodos: Estudo de abordagem quantitativa, observacional, descritivo, desenvolvido na unidade coronariana de um hospital público de cardiologia no Rio de Janeiro (RJ). Os dados foram extraídos de informações referentes aos pacientes, monitorização utilizada e da medição do tempo estímulo-resposta da equipe aos alarmes dos monitores multiparamétricos por observação de campo não participativa.

Resultados: Acompanhamos 88 pacientes (49 no serviço diurno e 39 no serviço noturno). O número total de alarmes de monitorização foi de 227 nas 40 horas de observação (20 horas no serviço diurno e 20 horas no serviço noturno), 106 alarmes no serviço diurno e 121 no serviço noturno, numa média de 5,7 alarmes/hora. Foram observados 145 alarmes sem resposta da equipe, 68 (64,15%) alarmes no serviço diurno e 77 (63,64%) no serviço noturno. Demonstramos que mais de 60% dos alarmes excederam o tempo-resposta de 10 minutos, considerados alarmes sem resposta. Obtivemos uma mediana de temporesposta dos alarmes atendidos de 4 minutos e 54 segundos no serviço diurno e 4 minutos e 55 segundos no serviço noturno. A monitorização da respiração encontrava-se ativada em apenas 9 pacientes (23,07%) no serviço noturno. Em relação à habilitação dos alarmes dessas variáveis, o alarme de arritmia estava habilitado em somente 10 (20,40%) dos pacientes no serviço diurno e o alarme da respiração em 4 pacientes (44,44%) no serviço noturno.

Conclusão: A programação e configuração de variáveis fisiológicas monitorizadas e parâmetros de alarmes na unidade foram inadequadas, houve retardo no tempo resposta e falta de resposta aos alarmes, sugerindo que alarmes relevantes podem ter sido ignorados pela equipe, comprometendo assim a segurança dos pacientes.

Descritores: Terapia intensiva/normas; Monitorização fisiológica/instrumentação; Alarmes clínicos; Segurança do paciente; Falha de equipamento; Unidades de terapia intensiva

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