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RESEARCH

Alarm fatigue and the implications for patient safety

Fadiga de alarmes e as implicações para segurança do paciente

Fatiga de alarmas y las implicaciones para la seguridad del paciente

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ABSTRACT

Objective: To measure the response time of health professionals before sound alarm activation and the implications for patient safety. **Method:** This is a quantitative and observational research conducted in an Adult Intensive Care Unit of a teaching hospital. Three researchers conducted non-participant observations for seven hours. Data collection occurred simultaneously in 20 beds during the morning shift. When listening the alarm activation, the researchers turned on the stopwatches and recorded the motive, the response time and the professional conduct. During collection, the unit had 90% of beds occupied and teams were complete. **Result:** We verified that from the 103 equipment activated, 66.03% of alarms fatigued. Nursing was the professional category that most provided care (31.06%) and the multi-parameter monitor was the device that alarmed the most (66.09%). **Conclusion:** Results corroborate the absence or delay of the response of teams, suggesting that relevant alarms might have been underestimated, compromising patient safety.
Descriptors: Nursing; Critical Care; Clinical Alarms; Biomedical Technology; Patient Safety.

RESUMO

Objetivo: Mensurar o tempo-resposta dos profissionais de saúde diante ao disparo dos alarmes sonoros e as implicações para a segurança do paciente. **Método**: Pesquisa quantitativa, observacional, em uma Unidade de Terapia Intensiva Adulto de um Hospital de Ensino. Os três pesquisadores realizaram observações não participativas durante 7 horas. A coleta de dados ocorreu simultaneamente em 20 leitos no período diurno. Ao ouvir o disparo, os pesquisadores acionavam os cronômetros e registravam o motivo, o tempo-resposta e a conduta profissional. Durante a coleta a unidade estava com 90% dos leitos ocupados e as equipes estavam completas. **Resultados**: Verificamos que, dos 103 equipamentos disparados, 66,03% dos alarmes fatigaram. A enfermagem foi a categoria profissional que mais atendeu (31.06%), e o monitor multiparâmetros alarmou (66,09%). **Conclusão:** Os resultados corroboram a ausência ou retardo de resposta da equipe, sugerindo que alarmes relevantes tenham sido menosprezados, comprometendo a segurança dos pacientes.
Descritores: Enfermagem; Cuidados Críticos; Alarmes Clínicos; Tecnologia Biomédica; Segurança do Paciente.

RESUMEN

Objetivo: Mensurar el tiempo-respuesta de los profesionales de salud delante del disparo de las alarmas sonoras, y las implicaciones para la seguridad del paciente. **Método:** Investigación cuantitativa, observacional, en una Unidad de Terapia Intensiva – Adulto de un hospital de enseñanza. Los tres investigadores han realizado observaciones no participativas durante 7 horas. La recogida de los datos ha ocurrido simultáneamente en 20 camillas en el período diurno. Al oír el disparo, los investigadores accionaban los cronómetros y registraban el motivo, el tiempo-respuesta y la conducta profesional. Durante la recogida, la unidad estaba con el 90% de las camillas ocupadas y los equipos estaban completados. **Resultados:** Certificamos que, de los 103 equipamientos que han sido disparados, el 66,03% de las alarmas han fatigado. La enfermería ha sido la categoría profesional que más ha atendido (el 31,06%), y el monitor multiparámetros ha alarmado (el 66,09%). **Conclusión:** Los resultados han corroborado la ausencia o el retardo de la respuesta del equipo, sugiriendo que las alarmas relevantes hayan sido menospreciadas, comprometiendo la seguridad de los pacientes.
Descriptores: Enfermería; Cuidados Críticos; Alarmas Clínicas; Tecnología Biomédica; Seguridad del Paciente.

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INTRODUCTION

In Intensive Care Units (ICU), the main causes of noises are related to equipment with acoustic alarms, whose objective is to alert the multiprofessional team on the alterations in the monitoring of patients, or even on its malfunction[1].

Regarding electromedical equipment, the complexity of configuration, programming and intervention of alarm systems for the management of the team was evidenced[2]. Failures of these equipment in intensive therapy, associated with adverse events, are portrayed in literature as a potentially serious factor for patient safety[3].

For many professionals in the healthcare team, alarms are commonly seen as expendable due to the high incidence of false positives, that is, without clinical importance. The longer the time of intervention, the higher will be the degree of risk for the patient's health, reducing his/her safety during hospitalization. Alarm fatigue is the implication of a resistance/desensitization in the perception of alarm signaling. Knowing how to decipher what was signaled by the sound of the device and understanding the profile of clinical importance represented by such activation determines the stimulus-response time, which is crucial to characterize if there is alarm fatigue or not[4].

When a large number of alarms are activated at the same time, suppressing other clinically significant alarms and allowing some relevant ones to be silenced, disabled or ignored by health professionals, the occurrence of alarm fatigue is verified. Absence of responses to relevant signals suggests impairment on safety and worsens the clinical conditions of patients in intensive therapy[5].

In Brazil, with the implementation of the National Policy of Patient Safety (*Política Nacional de Segurança do Paciente*), the institutions are encouraged to create new protocols besides those suggested by the program, aiming at promoting safety culture, risk management and especially patient safety[6].

Recent data from the Emergency Care Research Institute (Ecri), which is specialized in patient safety and use of electromedical equipment, point that, between 2012 and 2014, alarms had the first place among the ten health technology hazards, due the consecutive notifications of incidents related to alarms with patients hospitalized in the United States[7]. In 2017, the concern with the increase in adverse events related to alarms continued occupying the third place in the ranking list released by the Ecri[8-9].

Given these worrying data, our research is justified by the need to discuss the relationship between alarm fatigue and patient safety. This discussion will allow the proposal of improvements to the health care of the multiprofessional team and provide prevention strategies that ensure patient safety in healthcare institutions.

OBJECTIVE

To measure the response time of health professionals before sound alarm activation and the implications for patient safety.

METHOD

Ethical aspects

The study was approved by the Research Ethics Committee of the Faculdade de Ciências Médicas e da Saúde de Juíz de Fora (FCMS/JF), in compliance with Resolution 466/2012 of the Brazilian National Health Council. The inclusion of researchers in the field promoted the familiarization with the reality to be investigated and brought closer the potential participants for the presentation of the research proposal and later invitation to participate. Those who accepted signed the informed consent form.

Study design, location, and period

This is an observational and descriptive research with quantitative approach held at an Adult ICU with 20 beds of a public teaching hospital, located in a municipality of the Southeastern region of Brazil.

Data collection occurred in June 2016. During seven hours of observation in the morning shift, three researchers simultaneously collected the data in 20 beds previously distributed among them, with a mean of 1 hour of observation per day for seven days. We chose this strategy to evaluate the largest number of alarms activated concomitantly. The methodological option for the day shift was due to the familiarity of the researchers with the team, which did not occur in night shifts.

Population or sample; inclusion and exclusion criteria

The response time of healthcare teams to the alarms activated by electromedical equipment and the conducts adopted by professionals were evaluated. It is noteworthy that the composition of the healthcare team of the ICU fulfills the existing legislation and that, at the time of data collection, each professional category was complete. Therefore, every professional of the healthcare team was observed.

As for human resources, during daytime shifts (from 7:00 am to 7:00 pm), the nursing staff consists of two nurses and ten technicians, two doctors and two physical therapists. There is always a resident doctor on duty.

Inclusion and exclusion criteria for the response time of the healthcare team to the alarms were: a) inclusion criteria: alarms activated by a multi-parameter monitor, mechanical ventilator and continuous infusion pump; b) exclusion criteria: alarms considered inconsistent caused by manipulation during the procedures performed on patients.

Study protocol

Data collection occurred as follows: when hearing the the alarm activation, researchers turned on the stopwatches and unobtrusively moved to the beds, watching carefully not only the sound and visual signals of the electromedical device, but also the conduct of health professionals before the alarms. They timed the response time of the team and recorded the professional's conduct for data analysis. To this end, each researcher took a position at strategic locations, not to generate bias in the research result. The agreement was that, once the timing was initiated, in case a second alarm was activated, the latter would be ignored. When arriving at the sector, the noise level was measured in decibel (dBA) with the aid of a sound level meter and with a software for this equipment installed on the mobile device.

Analysis of results and statistics

For analysis, the frequency and percentage descriptive statistics was used to organize, summarize and describe the important aspects of a set of characteristics observed for the variables: a) inconsistent alarm; b) silenced the alarm; c) assessed and conducted intervention; d) fatigued alarm.

RESULTS

During data collection, a total of 103 activations was identified. The mean occupancy rate of the unit was 90% of the beds. The teams were complete.

Table 1 shows the number of alarms attended by each professional category and the mean time spent by professionals. Nursing staff was the category that most attended the alarms activated, with 31.06%. Subsequently, there were nursing technicians (29.12%) and nurses (1.94%); 2.91% of alarms were attended by other professionals within the multidisciplinary team. We verified that 66.03% of alarms investigated fatigued, and determined that no professionals attended these cases, which remained sounding for more than 10 minutes.

Table 1 – Professional category that attended the alarms from electromedical devices, Juiz de Fora, Minas Gerais, Brazil, 2016

Professional category	Number of alarms attended (%)	Mean time (min)
Nursing technician	29.12	3:40
Nurse	1.94	2:04
Physical therapist	1.94	1:04
Doctor	0.97	3:45

Table 2 – Factors that generated alarm activation, Juiz de Fora, Minas Gerais, Brazil, 2016

Physiological variables	Number of alarms (%)	Mean response time
HR	9.70	09:57
AP	36.07	08:50
SpO2	16.50	10:02
KVO (medication)	24.27	05:10
Peak P	3.88	03:54
PAP	1.94	06:31
Exp Flow	0.97	11:00
Loose Electrode	5.82	09:28

Note: HR – heart rate; PA – arterial pressure; SpO_2 – peripheral oxygen saturation; KVO – end of continuous pump infusion; Peak P – peak pressure; PAP – positive airway pressure; Exp Flow – expiatory flow.

Tables 2 and 3 show the factors that generate the sound alarms identified and the devices that promoted alarm activation the most, respectively. The electromedical device that activated the most was the multi-parameter monitor, with a total of 68 times (66.09%); among the factors observed, the one that activated the most the was arterial pressure (AP), with 37 times (36.7%), followed by peripheral oxygen saturation (SpO_2), 17 (16.5%), and heart rate (HR), 10 (9.7%).

The second electromedical device with more frequency was the continuous infusion pump, with a total of 25 times (24.27%), of which 22 (21.35%) were due to lack of medication, and of these, 5 (4.8%) fatigued. The device with the lowest incidence of activation was the mechanical ventilator, with 8 (7.76%) alarms, given that 4 (3.88%) were due to high peak pressure, 3 (2.91%) to positive airway pressure, and 1 (0.97) to expiratory flow.

Table 4 shows the conduct adopted by the healthcare team when attending the alarm. Given the activation, 17 (16.5%) health professionals evaluated and performed some kind of intervention for the benefit of the patient. The professionals silenced the alarms in 16 attendances (15.53%), and 5 (4.85%) were defined as inconsistent alarms, without clinical relevance.

Table 3 – Electromedical devices that activated the alarm, Juiz de Fora, Minas Gerais, Brazil, 2016

Electromedical devices	Number of alarms (%)	Mean response time
CIP	24.27	05:10
MM	66.09	09:21
MV	08.73	06:51

Note: CIP – continuous infusion pump; MM – multi-parameter monitor; MV – mechanical ventilator.

Table 4 – Conducts that professionals had before the alarm activated, Juiz de Fora, Minas Gerais, Brazil, 2016

Conducts	Number of alarms (%)	Mean response time to the alarm (min)
FA	66.03	10:26
IA	4.85	03:27
API	16.50	03:33
SA	15.53	03:33

Note: FA – fatigued alarm; IA – inconsistent alarm; API – assessed and performed intervention; SA – silenced alarm.

DISCUSSION

In the ICU investigated, the parameters are measured in a standardized form, i.e. the same physiological values are considered for all patients admitted to the unit, regardless of their pathology or need. Results of recent studies present similar characteristics, signaling that the findings on patient safety also involve reflection on the impact of the inclusion of technologies in critical care environments, due to the standardization of parameters of electromedical devices[10-12].

Our noteworthy findings suggest significant risks of occurrence of adverse events with patients observed, because more than 66% of the alarms were recorded without response, with response time over 10 minutes, and less than 26% of the alarms were attended in less than 5 minutes.

In 2014, a study conducted in Brazil in an ICU similar to our research showed that if these alarms signaled a tachycardia

or tachypnea in patients with sepsis, they could impair the prognosis. In a second example, if the alarms indicated a severe arrhythmia or instability, the lack or delay of the team's response to the alerts would result in serious consequences on patients' clinical conditions, since the changes would not be detected, preventing the adoption of appropriate therapeutic measures, which could impact the patient safety[11].

Regarding the cardiopulmonary resuscitation maneuvers, a time limit of 10 minutes was mentioned based on the guidelines of the American Heart Association. From the pathophysiological point of view, after 10 minutes of the beginning of cardiopulmonary arrest, in case the resuscitation maneuver is not initiated, inflammatory cytokines, free radicals and cell damage are released, causing myocardial changes, sometimes irreversible (stone heart), and severe neurological dysfunction[13].

Hence, with the objective of promoting patient safety, and avoiding possible clinical complications as well as alarm fatigues, it becomes necessary to emphasize the importance of alarms and review the time professionals take to attend them. In addition, we emphasize the need of health professionals thinking the importance of risk management related to technology, especially those which provide advanced life support in intensive care unit[14].

In data analysis, we noted that the multi-parameter monitor activated in 66% of times on average, with mean activation time of approximately 9 minutes. Our results show that the parameters, the programming and the volume of alarms from multi-parameter monitors, as well as the configuration of physiological variables, should be adopted as routine in the ICU, pondering the patient under severe conditions depends on this technological device for both diagnostic and therapeutic purposes as well as for improvement of his/her safety. With this practice, quality of care is promoted, which echoes in the teamwork process[15-16]. Such conducts decrease the noise, providing a less stressful environment.

The concern with the conduct before clinical alarms is present in several publications, among which we highlight the findings of the study in which researchers measured the stimulus-response time of a team to the alarms of multi-parameter monitors in a coronary care unit. More than 60% of the alarms were considered to be fatigued, and less than 20% were attended within 10 minutes[10]. In another investigation study on the stimulus-response time of the team to alarms activated due to the monitor, during monitoring of invasive blood pressure, there was a record of 76 alarms, of which 21 were attended with mean response time of 2 min and 45 seconds. The 55 remaining alarms were defined as fatigued by the authors because there was no response on the part of professionals[17].

The research indicated that part of the healthcare team is desensitized to the alarm caused by continuous infusion pump, because more than 24.27% of the activations had no intervention. Studies show that approximately 30% to 60% of all harmful mistakes with intravenous medication are related to the continuous infusion pump. Many of these mistakes occur during the programming, especially in the adjustment of the infusion speed and when the professional despises the alarm activation, which can cause excessive medication, overdose and even the non-infusion[17-18]. Another study identified an alarm activation for 15 minutes without anyone verifying what was happening and, in another situation, a professional silenced the alarm professional and did not communicate the healthcare team[9].

It is known that the medication process is complex and characterized by the practice of several professionals marked by fragility. It becomes necessary to raise awareness of nurses about the training of the healthcare team on inappropriate handling of equipment, allowing the discussion of strategy that promotes quality in care[10,17-18].

Another important data from the study was the low number of alarms generated by the mechanical ventilator, representing 8.73% of the activations, with only one effective service performed by the nursing staff. The mechanical ventilator is one of the main life support resources used in ICU. Mechanical ventilator means using a machine that replaces, totally or partially, the patient's respiratory activity, with the objective of restoring the balance between supply and demand of oxygen (O_2), decreasing the respiratory workload of patients on ventilatory failure[19-20].

In a study conducted in 2013, which evaluated alarm fatigue in electromedical devices, researchers found that no alarm from mechanical ventilators was fatigued because most of activations of the device had short duration, some up to 4 seconds. It was noticeable, in the environment researched, that the sound of the mechanical ventilator draws more attention, and that health professionals demonstrate greater reaction to this alarm when compared to others. Although these alarms were not fatigued, due to their large number, they significantly compete to the fatigue of other alarms[1].

Alarms from the mechanical ventilator are intended to warn the healthcare team on any hemodynamic alteration in the patient. For the appropriate use of this technology, alarms should be adjusted and managed by the team, aiming at providing a safe care. Therefore, on the part of professionals, knowledge about the possible causes of activation and about the outcome for the patient is mandatory given that the response time of the multiprofessional team, when ineffective, suggests a multifaceted problem because it involves human factors, equipment, alarm devices and components of the workflow[11].

Another serious issue to consider is the noise level in units. Our research showed that the decibel mean was 75 dBA, i.e. approximately 66.6% above the level recommended: the Brazilian Association of Technical Standards (ABNT – *Associação Brasileira de Normas Técnicas*) establishes 45 dBA as the acceptable limit of sound level in internal environments[21]. The findings suggest that alarm fatigue associated with the high level of noises found in the institution contributes to lack of concentration, stress and decrease of the attention of healthcare team, leading to an environment susceptible to considerable risks and compromising patient safety[7].

As for human resources, results evidenced few procedures adopted with regard to adjustment of monitors, programming and measurement of patients' vital parameters, correction of the continuous infusion pump infusion, and verification as well as correction of parameters of mechanical ventilators. Such conducts demand professional knowledge to evaluate the patient's

clinical condition and the parameterization of electromedical devices individually and according to its pathology.

In this regard, studies show that there is a prevalence in the lack of adherence of teams, factor determined by the limited interdisciplinary training, directed to programming and configuration of alarms, generating little awareness on the urgency of attending the alarms. This can be one of the factors that contribute to the occurrence of routine violations and that result in adverse events[2,11,22].

In this respect, it is important for the healthcare team to be attentive to the mutual work, cooperating for interdisciplinary knowledge and enabling the process of communication in prevention of incidents. For thus, the premise of communicational competence in ICU is mandatory, allowing the organization, identification and establishment of goals; in addition to the solution of problems focused in increasing the efficiency of the work unit and its complete organization[23].

Study limitations

The fact that the data was collected in only one center and that there is a possibility of Hawthorne effect regarding the presence of researchers can be cited as limitations of this study.

Contributions to the fields of nursing and health

We emphasize the importance of managing alarms in ICU because the problem permeates from the social environment to the economic costs and financial implications. Therefore, the maturation of the team is mandatory regarding the knowledge, interpretation, clinical reasoning and scientific decision making with ethical attitudes, promoting quality in service and especially putting into practice care proposals focused on patient safety.

For the effective response to alarms, a training with realistic simulation in educational institutions is necessary, with quarterly periodicity, both in subjects directed to critical patients at undergraduate courses as *lato sensu* specialization classes . In addition, there must be a previous training and preparation of health professionals to the correct handling of equipment and for actions on patient safety through permanent education centers in services, with approaches that involve everyday situations in the ICU. This attitude will probably decrease the number of adverse events and will consequently encourage a patient safety culture.

CONCLUSION

The results of the research corroborate the absence or delay of the response of the healthcare team before the monitoring sound alarms in the ICU, suggesting that relevant alarms might have been underestimated, thus compromising patient safety.

The variables of the study indicate that patient safety has direct correlation with the correct handling of electromedical equipment, alarm systems and human resources. Noting that the unit investigated had no protocol for parameterization of devices and management of risks related to alarm fatigue, the index of fatigued alarms in the service is a matter of concern. It is worth emphasizing that nursing was the professional category that most attended the alarms, suggesting the desensitization of other professionals to the activations.

The technological device in the ICU has as function to alert professionals about potential alterations in both devices and patients, promoting the alarm activation. Therefore, it is imperative for the multidisciplinary team to understand its importance and to become more attentive to the signs.

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