Revista Brasileira de Enfermagem
REBEn

Individualized parameterization of multiparametric monitors alarms in infarcted patients

Parametrização individualizada de alarmes de monitores multiparamétricos em pacientes infartados

Parametrización individualizada de alarmas de monitores multiparamétricos en pacientes infartados

Allan Peixoto de Assis[I]
ORCID:0000-0002-1362-8855

Francimar Tinoco de Oliveira[II]
ORCID:0000-0001-7477-6723

Flávia Giron Camerini[III]
ORCID:0000-0002-4330-953X

Roberto Carlos Lyra da Silva[IV]
ORCID:0000-0001-9416-9525

Camila Mendonça de Moraes[I]
ORCID:0000-0001-5544-8409

[I] *Universidade Federal do Rio de Janeiro, Campus Macaé. Macaé. Rio de Janeiro, Brasil.*
[II] *Universidade Federal do Rio de Janeiro, Escola de Enfermagem Anna Nery. Rio de Janeiro, Rio de Janeiro, Brasil.*
[III] *Universidade do Estado do Rio de Janeiro, Faculdade de Enfermagem. Rio de Janeiro, Rio de Janeiro, Brasil.*
[IV] *Universidade Federal do Estado do Rio de Janeiro, Escola de Enfermagem Alfredo Pinto. Rio de Janeiro, Rio de Janeiro, Brasil.*

How to cite this article:
Assis AP, Oliveira FT, Camerini FG, Silva RCL, Moraes CM. Individualized parameterization of multiparametric monitors alarms in infarcted patients. Rev Bras Enferm. 2019;72(3):609-16. doi: http://dx.doi .org/10.1590/0034-7167-2018-0485

Corresponding Author:
Allan Peixoto de Assis
E-mail: allanpeixoto@macae.ufrj.br

Submission: 06-10-2018 **Approval:** 02-01-2019

ABSTRACT

Objective: To measure the magnitude of the effect of an individualized parameterization protocol for hemodynamic alarms in patients with acute myocardial infarction. **Method:** Pragmatic clinical trial, open label and single arm, whose intervention was performed through a protocol validated and tested in 32 patients using multiparametric monitors. The heart rate, blood pressure, respiratory rate, oxygen saturation and ST segment-monitoring were measured and classified for clinical consistency one hour before and after the intervention, for 64 hours. **Results:** The protocol obtained Content Validity Index of 0.92. Of the 460 registered alarms, 261 were considered inconsistent before the intervention and 47 after it. The Relative Risk of inconsistent alarms after the protocol was 0.32 (95% CI 0.23-0.43, p <0.0001). **Conclusion:** The protocol proved to be a protective factor to the appearance of inconsistent clinical alarms of multiparametric monitors.
Descriptors: Clinical Alarms; Physiological Monitors; Parameters; Myocardial Infarction; Nursing Care.

RESUMO

Objetivo: Medir a magnitude do efeito de um protocolo de parametrização individualizada de alarmes hemodinâmicos em pacientes com infarto agudo do miocárdio. **Método**: Ensaio clínico pragmático, *open label* e *single arm*, cuja intervenção ocorreu por meio de um protocolo validado e testado em 32 pacientes usando monitores multiparamétricos. Os alarmes de frequência cardíaca, pressão arterial, frequência respiratória, saturação de oxigênio e segmento ST foram mensurados e classificados quanto à consistência clínica uma hora antes e após a intervenção, durante 64 horas. **Resultados**: O protocolo obteve Índice de Validade de Conteúdo de 0,92. Dos 460 alarmes registrados, 261 foram considerados inconsistentes antes da intervenção e 47 após. O Risco Relativo de alarmes inconsistentes após o protocolo foi de 0,32 (IC 95% 0.23-0.43, p<0,0001). **Conclusão**: O protocolo mostrou-se um fator protetor ao surgimento de alarmes clínicos inconsistentes de monitores multiparamétricos.
Descritores: Alarmes Clínicos; Monitor Fisiológico; Parâmetros; Infarto do Miocárdio; Cuidados de Enfermagem.

RESUMEN

Objetivo: Medir la magnitud del efecto de un protocolo de parametrización individualizada de alarmas hemodinámicas en pacientes con infarto agudo de miocardio. **Método:** Ensayo clínico pragmático, *open label* y *single arm* cuya intervención ocurrió por medio de un protocolo validado y testado en 32 pacientes, utilizándose monitores multiparamétricos. Las alarmas de frecuencia cardíaca, presión arterial, frecuencia respiratoria, saturación de oxígeno y segmento ST fueron valorados y clasificados según su consistencia clínica, una hora antes y después de la intervención, durante 64 horas. **Resultados:** El protocolo obtuvo un índice de Validez de Contenido de 0,92. De las 460 alarmas registradas, 261 fueron consideradas inconsistentes antes de la intervención y 47 después. El Riesgo Relativo de las alarmas incoherentes después del protocolo fue de 0,32 (IC 95% 0.23-0.43, p <0,0001).
Conclusión: El protocolo se mostró un factor protector al surgimiento de alarmas clínicas inconsistentes de monitores multiparamétricos.
Descriptores: Alarmas Clínicas; Monitor Fisiológico; Parámetros; Infarto de Miocardio; Cuidados de Enfermería.

INTRODUCTION

Clinical alarms of multiparametric vital signs monitors must alert caregivers that something is not right and direct them to prompt action. Therefore, it is an indispensable technology to care for severe patients, especially those with acute myocardial infarction (AMI)[1].

Due to the severity of the disease, patients with AMI must be observed in beds with multiparametric monitors for the early detection of hemodynamic instabilities and life-threatening arrhythmias[2]. In this case, responding to clinical alarms of ventricular fibrillation (VF), for example, prevents death or an unfavorable neurological outcome, inversely proportional to the time of its care[3].

Despite that, clinical alarms can often sound false or inconsistent. Inconsistent clinical alarms are those that do not present reliable clinical data about the patient and may occur from 80% to 99% of the time in hospital units. They can also compromise the health team's response time[4]. Current data on the consistency of clinical alarms indicate a frequency of only 5% to 13% of monitor alarms that required some immediate action by the team[5].

Among the consequences, a phenomenon known today as "alarm fatigue" is highlighted, identified when a large number of alarms obscure those clinically significant, causing team indifference to them and allowing alarms of clinical consistency to be ignored, silenced, or even disabled, compromising patient safety[6].

Several adverse events are being related to alarm fatigue. The Joint Commission (TJC) recorded 98 events related to medical-care equipment (MCE) alarms between January 2009 and June 2012; of these events, 80 evolved to death, 13 led to permanent functional disability and 5 to hospital care and longer hospitalization[7-8].

Aiming at reducing these adverse events, the Association for Advanced Medical Instrumentation (AAMI) promoted, in 2011, a Summit meeting that brought together several professional entities to discuss the quality, safety and management of clinical alarms. It is worth noting that the individual customization of the limits in multiparametric monitors (considering baseline parameters and tendencies of variation in a clinical context of the patient) was one of the main strategies pointed out as a way to make them more reliable and safe[9].

In addition, TJC launched "Reducing damages associated with clinical alarm systems" as a new international safety goal, scheduling its compliance in two phases for health institutions to better adapt to it. In phase I, which began in January 2014, hospitals were instructed to place alarms as a priority for organization, to choose the most important alarms, and to structure tools to manage them according to their local realities. For phase II, which began in January 2016, TJC expects hospitals to develop and implement specific policies and procedures to manage alarms[7].

Given the aforementioned, a parameterization protocol for alarms of hemodynamic variables, specifically for patients with AMI, was elaborated and validated, aiming to support professionals in the configuration of the clinical alarms of the monitors according to individual characteristics and therapeutic targets. This led to the following research question: *Does the use of a parameterization protocol for hemodynamic variables alleviate inconsistent clinical alarms in patients with AMI?*

The structured research question was thus defined according to the acronym PICO – Population: adult patients with an AMI diagnosis, who are hospitalized in coronary intensive care units; Intervention: application of a parameterization protocol for hemodynamic alarms; Control: no protocol application; Outcomes: reduction in the number of inconsistent clinical alarms triggered.

OBJECTIVE

To measure the magnitude of the effect of an individualized parameterization protocol for hemodynamic alarms in patients with acute myocardial infarction.

METHODS

Ethical aspects

The development of the study complied with Resolution 466/12 of the National Health Council and was approved by the Ethics and Research Committee (CEP) of the proposing and co-participating institutions.

Study design, place and period

A quantitative, pragmatic clinical trial[10], open label and single arm study, whose outcome was evaluated before and after the intervention of parameterization of monitors, using the study protocol. To guide the method was used from the Equator network the *CONSORT Extension for Pragmatic Trials Checklist*. The outcome of interest was evaluated through direct observation of the multiparametric monitors and the patients for 64 hours. Research was performed at the Coronary Unit of a large federal hospital, specialized in Cardiology. Data were produced from March to July 2016.

Population, inclusion and exclusion criteria

The population of this study consisted of 32 individuals of both sexes, aged over 18 years old, victims of AMI with ST-segment elevation (supra-infarct) or non-ST-segment elevation (non-supraventricular myocardial infarction) hospitalized in the study's setting, undergoing the acute phase of treatment and using multiparametric monitors. Sampling was for convenience, considering the eligibility criteria.

Patients with incomplete hemodynamic monitoring (any monitor coupled to the patient with less than five electrodes, absence of blood pressure lead or pulse oximetry) and/or out of the acute phase (period agreed upon in the study as up to seven days after the insult) were excluded from the sample.

To increase the possibilities of capturing the clinical alarms of the sample and their relation with the observed outcome, there were no restrictions regarding the degree of risk for subjects, any category of Thrombolysis in Myocardial Infarction (TIMI) or the Global Registry of Acute Coronary Events (GRACE), or any degree of left ventricular dysfunction by the Killip Classification.

Study protocol

An individualized parameterization protocol for alarms of hemodynamic variables in patients with acute myocardial infarction

– called ProPIAM – was elaborated based on current literature data[11-13] on the values considered safe for each range of physiological variation of hemodynamic parameters of each patient. ProPIAM was elaborated with fourteen items called "steps", precisely to serve as a guide during its application. Each step indicates an action to be taken in relation to the multiparameter monitor of patients with AMI.

Its content was validated by a group of 11 judges, who are nurses and physicians with expertise and experience in Cardiology and/or Intensive Care, considering a minimum content validity index (CVI) of 0.80 for each step. The steps of ProPIAM were validated with a total CVI of 0.92, its presentation together with its respective level of evidence, according to the classification of the American Association of Critical Care Nurses[14] (AACN). Information is shown in Chart 1.

Chart 1 – Fourteen steps of ProPIAM and their levels of evidence. Rio de Janeiro, RJ, Brazil, 2017

Steps of ProPIAM	Action	Level of evidence
1	Prepare the skin by cutting hairs and perform astringency with soap and water in the chosen places for adherence of the electrodes; dry the area with a towel or gauze.	B
2	Choose five-wire monitoring systems: Right Arm (RA), Left Arm (LA), Left Leg (LL), Right Leg (RL) and Chest (C).	E
3	Adhere the electrodes to the following anatomical references: RA – Right infraclavicular fossa; LA – Left infraclavicular fossa; LL – Below the left rib cage; RL – Below the right rib cage; C – In the desired precordial derivation (V1 to V6).	E
4	Adhere the electrodes considering the electrode C for the precordial derivation that showed a change in the ST segment on the electrocardiogram (ECG) of admission OR in the V3 derivation for patients with AMI without previous ST segment changes OR according to the obstructed artery in cardiac catheterization. V2 or V3 correspond to the injury of the anterior descending artery (ADA); V3R or V4R to the injury of the right coronary artery injury (RCA); and V1, V2 or V3 (where the mirror image is) to the posterior descending artery (PDA).	E
5	Consider electrode C in V1 for suspected right bundle branch block (RBBB) or left bundle branch block (LBBB) to confirm temporary transvenous pacemaker placement and distinguish between ventricular tachycardia and supraventricular tachycardia with aberrancy.	E
6	Choose the monitor with on-screen derivations using the same altered derivations for the ECG of admission. If there are no ECG changes, keep DIII and V3. If there is any arterial injury demonstrated in the cardiac catheterization with no ECG changes, maintain V2, V3 and/or V4 for ADA injury; DIII and V3R and/or V4R for RCA injury; DI, aVL and/or V5 for the Circumflex Artery (CA) injury; and V1, V2 and/or V3 (where the mirror is) for PDA injury.	E
7	Continuously measure non-invasive blood pressure using the oscillometric technique and a cuff that corresponds to 40% of arm circumference and 80% of its length. The cuff should be at the point which indicates the brachial artery, at 2.5 cm above the antecubital fossa. The patient should be lying down with the arm resting at the level of his/her heart.	B
8	Continuously monitor invasive blood pressure, with signal transduction system positioned at the level of the phlebostatic axis (4th intercostal space at the middle axillary line), with dynamic curve visualization and pressurized pocket at 300 mmHg.	E
9	Measure the pulse oximetry in a quantitative waveform through the plestimographic method, with signal recognition by light. The probe (transmitter sensor) should be located at distal ends such as ear lobes or fingertips. They must be in a contralateral limb, with a noninvasive blood pressure cuff. Any material that impedes the penetration of infrared radiation into the skin should be removed.	M
10	Set the Heart Rate alarms between 50 and 70.	B
11	Set ST segment alarms at roughly 1-2mm below the baseline or the ST segment pattern displayed by the patient on the ECG of admission up to 0.60s from the J point.	E
12	Adjust systolic blood pressure alarms between 90 and 140mmHg; diastolic blood pressure between 52 and 90mmHg; and mean arterial pressure between 65 and 105mmHg.	B
13	Set the Heart Rate alarms between 12 and 20 bpm.	E
14	Adjust the alarms of peripheral oxygen saturation between 90% and 97% in non-COPDs and without the use of O2; between 93% and 97% in non-COPD patients with the use of O2; between 88% and 97% in COPD patients without the use of O2; and between 90% and 97% in COPD patients with the use of O2.	B

Note: COPD – Chronic Obstructive Pulmonary Disease; O2 – Oxygen.

To measure the clinical alarms before applying the ProPIAM, all the alarms coming from the variables Heart Rate (HR), ST segment (STS), Blood Pressure (BP), Respiratory Rate (RF) and Peripheral Oxygen Saturation (SpO2) had to be recorded, for one hour per patient. Evaluating the alarm was performed by a nurse with expertise and experience in the area. To judge the "clinical inconsistency" of the alarm, at the time it went off for one of the hemodynamic variables, the following question was answered with yes (Y) or no (N): Does the alarm reflect any relevant clinical condition? If the answer was "N", the alarm was considered inconsistent.

If the alarm reflected a relevant clinical condition, representing a threat to the health status of the patient, the investigator immediately informed the nurse responsible that the relevant actions were taken and the alarm was considered consistent.

The physical examination at the bedside was rigorously performed by the researcher to validate whether or not alarms reflecting a possible relevant clinical condition.

After the first hour observing, quantifying and qualifying clinical alarms, the patient was individually submitted to the intervention steps indicated by ProPIAM. Alarms continued to be measured and qualified for their clinical consistency for an additional hour.

Analysis of results and statistics:

To assess the impact of using the ProPIAM on the studied population, the protocol was tested by comparing the number of inconsistent and consistent clinical alarms, before and after its application, and by evaluating the magnitude of its effect. The comparison between the clinical alarms was performed by the chi-squared test (X^2). The magnitude of the effect was evaluated using measures of effect and association.

Data were imported into the R Commander® program, version 3.3.2. The variables of primary outcome of the clinical alarms under the Poisson model were used, followed by the calculation of the RR (Relative Risk) and the RRR (Relative Risk Reduction). The chi-squared test was used to compare the frequency of clinically inconsistent and consistent alarms, before and after the intervention. It was considered a statistically significant difference for the probability a value lower than 0.05 (p value <0.05).

RESULTS

ProPIAM was applied to a number (n) of 32 patients with AMI. The average age was 62, with a standard deviation (SD) of 8.36, with a predominance of males 20 (62.5%). Regarding the presentation of AMI, 20 (62.5%) of the patients presented AMI with an ST deflection, mostly of anterior wall, 12 (37.5%), with an average post-insult time of 5.5 days (SD=1.79). As for risk rating, the majority were characterized as Killip I 23 (71.8%), TIMI risk between 0 and 2 14 (4.8%) and Grace Risk < or = 108 17 (53.2%), which mostly represents patients with low-risk AMI,. The detailed characterization of the sample is shown in Table 1.

Sixty-four hours of observation were made, only in the day shift, distributed in 20 days (average of 3.2h/day). A total of 460 clinical alarms (7.2 alarms/hour) were collected. In the pre-parameterization period, there were 295 alarms (9.21 alarms/patient/hour) and in the post-parameterization period, 165 alarms (5.15 alarms/patient/hour). There was a 44% reduction in the number of alarms previously observed. Of the 295 pre-parameterization alarms, 88.5% were considered inconsistent; of the 165 post-parameterization alarms, 28.5% were inconsistent.

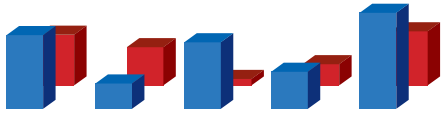
In hemodynamic parameters, SpO2 and HR were analyzed, which represented the variables that most alarmed in the pre-parameterization and post-parameterization groups. The SST alarm was the one that most reduced with the use of the protocol. The BP-related alarm, in an opposite and isolated way, increased in the post-parameterization group (Graph 1).

Regarding the clinical consistency of the alarms, all the hemodynamic variables presented alarms with less inconsistency after applying the protocol, mainly the STS, SpO2 and HR alarms. In the case of BP alarms, the increase in their frequency in the post-parameterization period occurred at the expense of an increase in their clinical consistency (Table 2).

Table 1 - Characterization of the sample of patients in the acute phase of AMI, included in the study. Rio de Janeiro, RJ, Brazil, 2017. (n=32)

Variables	Sample n(%)	Variables	Sample n(%)
Sex		Risk rating	
Male	20 (62.5)	Killip Classification	
Female	12 (37.5)	Killip I	23 (71,8)
Age		Killip II	7 (21,8)
<60 years old	13 (40.6)	Killip III	1 (3,2)
>60 years old	19 (59.4)	Killip IV	1(3,2)
Type of AMI		TIMI** Risk	
Supra-infarct	20 (62.5)	0-2	14 (43.8)
Non-supra infarct	12 (37.5)	3-4	12 (37.5)
AMI Extension		>4	6 (18.7)
Anterior wall	12 (37.5)	GRACE** Risk	
Inferior wall	7 (22)	<or=108	17 (53.2)
Lateral wall	4 (12.5)	109-140	9 (28.1)
Anteroseptal wall	4 (12.5)	>140	6 (18.7)
Anterolateral wall	1 (3.2)		
No register*	4 (12.5)		

*Note: *Representing the patients without indication of myocardial injury on the ECG. **TIMI - Thrombolysis in Myocardial Infarction; GRACE - Global Registry of Acute Coronary Events.*



	HR	BP	STS	RR	SpO2
Pre-parametrization	70	24	64	35	92
Post-parametrization	48	36	6	20	51

Note: HR – Heart rate; BP – Blood pressure; STS – ST segment; RR – Respiratory rate; SpO2 - Peripheral oxygen saturation.

Graph 1 –Distribution of the clinical alarms that went off before and after the intervention by hemodynamic parameter. – Rio de Janeiro, RJ, Brazil, 2017

The relevance of the effect of the ProPIAM on the sample studied and the probability of observing this effect at random are presented in Table 3.

In addition to a significant reduction in the total number of clinical alarms that went off, the increase in consistent alarms, and decrease in inconsistent alarms, the association measures also revealed that the protocol was a protective factor for the "inconsistent clinical alarm" (RR=0.32) and responsible for 68% of its reduction in the post-parameterization group.

Table 2 - Distribution of the frequency of consistent and inconsistent alarms, before and after the parameterization by hemodynamic parameter – Rio de Janeiro, RJ, Brazil, 2017

Parametrization	Alarms	HR n(%)	BP n(%)	STS n(%)	RR n(%)	SpO2 n(%)
No	Consistent	17 (3.7)	11 (2.4)	3 (0.7)	0	5 (1.1)
	Inconsistent	53 (11.5)	13 (2.8)	61 (13.2)	35 (7.6)	87 (18.9)
Yes	Consistent	43 (9.3)	36 (7.8)	6 (1.3)	3 (0.65)	23 (5)
	Inconsistent	5 (1.1)	0	0	17 (3.7)	28 (6.1)

Note: HR – Heart rate; BP – Blood pressure; STS – ST segment; RR – Respiratory rate; SpO2 - Peripheral oxygen saturation.

Table 3 - Distribution of the frequency of clinical alarms before and after parameterization and their association measures – Rio de Janeiro, RJ, Brazil, 2017

Parametrization	Inconsistent alarms n(%)	Consistent alarms n(%)	p-value	RR (CI 95%)	RRR
No	261 (88.5)	34 (11.5)	<0.0001	0.32 (0.23-0.43)	68%
Yes	47 (28.5)	118 (71.5)			

Note: RR – Relative Risk; CI – Confidence Interval; RRR – Reduction of the Relative Risk

DISCUSSION

The results from the use of ProPIAM showed that, after parameterization, the total number of clinical alarms and the number of clinical alarms classified as "inconsistent" dropped significantly (p<0.0001). There was a 68% efficacy in reducing inconsistent alarms in the study sample, with a relative risk of 0.32. For this reason, this is a protective factor over the outcome of inconsistent clinical alarms.

Individualized parameterization of alarms is also recommended by AACN, which published a "Practical Alert" on the management of clinical alarms in 2013 as a way to combat the phenomenon of alarm fatigue[4]. The activities related to skin preparation for electrode adhesion, customization of clinical alarm limits, formation of a work team and the permanent education of the team regarding the use of monitors were highlighted in this document as essential to the routine of intensive therapy.

This study can be considered a response to the goals set by both Summit meeting in 2011[9] and the TJC[7], as it proposes a procedure (ProPIAM) for this purpose. It shows a decrease from 9.21 to 5.15 in alarms per patient per hour, almost half of the total number of alarms found in the sample.

A study with purposes and results like those found here was conducted at the Dartmounth-Hitchcock hospital in Vermont, USA. A consensus by experts developed an alarm management system for patient monitoring and surveillance. Parameters were used to set alarm limits, delays for some alarms and the team's continuing education. At the end of six months, there was a drop from seven to two alarms per patient-hour in the pilot unit[15].

An observational and prospective study, which sought to manage the alarms of an adult intensive care unit (ICU) for six months, through a non-individualized parameterization of alarm limits, presented as a main outcome a 43% drop in the total number of alarms that went off in the unit. Reports given by nurses also found a decrease in excessive noise and a higher rate of alarms not ignored by the team[16].

Another study implemented a new policy of continuous cardiac monitoring in a 360-bed hospital by applying a protocol elaborated by the American Heart Association (AHA), based on the same monitoring guideline, from 2004, used in the elaboration of ProPIAM. It sought to reduce the number of inconsistent alarms and improve the response of alarms in general. In a similar way to the results presented, the percentage of inconsistent alarms decreased significantly (from 18.8% to 9.6%, p<0.001), showing no impact on the rates of hospitalization and mortality[17].

More recently, a systematic review sought to find interventions that have been successfully used to reduce alarm fatigue. Changes in pre-defined settings of alarms due to patients' needs, daily electrode changes, rounds on clinical alarms, and team education in the use of the technologies were pointed out as successful interventions, although the study did not demonstrate a single strategy solution to the problem but an integration of multiple strategies with synergistic benefits[18].

There are also studies that found results different from those found here. A pilot project, which carried out changes in the configuration units of 17 clinical alarms and training of the nursing team on good practices for monitoring a 20-bed cardiac ICU, aimed at reducing alarm rates and improving the attitudes and practices of nurses. After 10 weeks of intervention, the alarm rate fell (87.86 alarms/patient/day vs. 59.18 alarms/patient/day), but without statistical significance (p-value=0.01). Of the 39 nurses, 24 (62%) returned the questionnaires without evidence of significant changes in their attitudes in the post-intervention period. Half of the nurses specified the need for more training to handle cardiac monitors[19].

Another publication also failed to find the effectiveness of the individualized parametrization strategy applied in a 10-bed trauma-orthopedic ICU. The number of alarms increased in the post-intervention period by 36.4%, with an increase in the number of inconsistent alarms (from 91.1% to 97%) and the fatigue alarm rate (99.7%)[20]. Despite the biases pointed out, it is worth noting that the parameterization was carried out differently from the one proposed here. Adjustments were made with reference to the baseline values found in the pre-intervention period, giving them a range of variation on an average trend of vital signs. On the other hand, the ProPIAM parameterized the hemodynamic variables based on the therapeutic targets of patient with AMI. The safe bands of variation were set according to the international guidelines already mentioned.

Although the studies cited above have the same purpose of this study, they were carried out with heterogeneous populations and under different methodological designs. ProPIAM was applied exclusively to patients of a nosological condition (AMI), with a recent clinical presentation (acute phase) and used therapeutic targets to parameterize the alarm limits and not the average of vital sign trends. Moreover, the focus of this study was not to reduce the total number of clinical alarms, but its clinical inconsistency: the drop in the total number of alarms is only a consequence. If the number of alarms increased with the application of the protocol, even if there was improvement of its clinical consistency, the results would meet expectations.

Alarm management and individualized parameterization must have the clinical condition of each patient as their focus, and not the physiological baseline values of each vital function. These are sick and unhealthy people. Each has their definition of normality. A patient with pulmonary fibrosis may have a regular SpO2<90%

and a patient using a beta-blocker a regular HR<55bpm. The clinical alarm should inform that patients present clinical changes relevant to their context[21].

Once the data of the present study were deepened, as for the alarms that went off during the clinical test of ProPIAM, the variables of SpO2, HR and STS variables were the most inconsistent before the protocol application. Although all of them showed a decrease with the use of ProPIAM, STS alarms were the most reduced ones after parameterization. In several other studies, there were also high amounts of inconsistent SpO2 and HR alarms[15,19,22-24], with causal surveys converging to poor adhesion of skin electrodes, inadequate alarm trigger limits, maladaptation of the oximetry probe and lack of an alarm management policy in the units studied.

The alarms of STS are rarely mentioned in most studies because they are often disabled in monitors. Only one study, conducted exclusively with patients with a heart disease, registers high numbers of clinically inconsistent alarms of STS and links this cause mainly to patients who already have individual ST segment elevations and/or some intrinsic condition that contraindicates such monitoring, such as branch block and tachycardias with aberrancy, causing inconsistent alarms of STS[23].

The alarms of STS need to add value to clinical surveillance. For this purpose, nurses need to understand the importance of such alarms and develop skills for their configuration. If those responsible for the surveillance do not understand the value of an STS alarm, this piece of equipment should be disabled instead of maintained, since the lack of individualized parameterization will surely produce inconsistent alarms and potentially generate adverse events for patients[11].

For configuring the alarms of STS parameterized in the study, the ECG and the characteristics of the ST segment, like the J point and their differences in millimeters below or above the baseline had to be analyzed, besides the identification of the injured wall. It is clear that, to use the STS alarm, nurses must have knowledge and skills to interpret electrocardiograms and to manipulate the monitor functions for this variable.

The implementation of measures of impact on the management of SpO2, HR and STS alarms already recommended in the literature is of utmost importance, such as the preparation of the skin for the adhesion of electrodes, their replacement in an appropriate period (within 24 hours), the use of an oximetry reading device with good end-to-end adaptation, disabling oximetry in patients with poor peripheral perfusion, correct ST-segment alarm configuration, daily monitoring of the soundness of monitoring cables, adjusting the gain of the R wave and the need to apply short delays of some alarms, especially those of SpO2[25,26].

Contrary to that observed in all hemodynamic variables of the study, the BP variable was more alarming after the application of ProPIAM. However, this increase was accompanied by an increase in its clinical consistency. It is worth mentioning that the parameterization of the BP alarms did not follow any specific recommendation for patients with AMI because there was no such record in the literature, only referring to the Brazilian Hypertension Guidelines. It is questioned whether such consistent alarms reflected a positive impact on patient surveillance of the study, since they were not based on specific hemodynamic targets of AMI.

The management of multiparametric monitors alarms in an ICU is a complex activity for involving human beings. The use of parameterization tools such as ProPIAM only delimit facilitating actions. However, to effectively manage alarms, professionals need motivation, the availability of institution policies and procedures, training adequacy and usability of electronic equipment.

Usability is "the ability of a product to be used by specific users to achieve specific objectives with efficiency, effectiveness and satisfaction in a specific context of use". That is: the ideal interaction between men and equipment (in this case, the multiparameter monitor) to extract the necessary functions, which will be useful to provide care. Usability should be considered as an extremely important factor for the management of alarms in the ICU[27].

The creation of institutional policies for the management of alarm systems requires human involvement, changes in behavior regarding alarms and, above all, professional awareness of legal responsibility towards patients. Parameterization is a strategy that needs to be carried out at the bedside, in a periodic and individualized way. It characterizes the human interaction with the machine and the rational use of its resources to benefit the patient that is connected to it.

Study limitations

Given data collection was performed by a single researcher, among other factors related to the data collection setting, the possible conditions for the study did not allow a randomized, controlled and double-blind clinical trial. Therefore, the choice made was to construct an uncontrolled clinical trial or a pragmatic clinical trial[10], as described. The study did not focus on measuring the time between the stimulus and the response of professionals, which would make it possible to identify the incidence of fatigued alarms with the intervention.

Contributions to the Nursing field

In this study, what is highlighted is the positive effect of an individualized parameterization protocol for hemodynamic alarms in patients with acute myocardial infarction for the clinical Nursing practice. This is due to the significant decrease in the total number of clinical alarms that went off, the increase in consistent alarms and decrease in inconsistencies, thus affecting a more reliable and trustworthy practice of them. Therefore, the use of evidence-based protocols means aiming at an excellent care for patient safety.

CONCLUSION

The impact of the individualized alarm parameterization strategy on patients with AMI. through testing a previously elaborated and validated protocol (CVI-T=0.92) – ProPIAM – showed a significant drop ($p<0.0001$) in the results of inconsistent clinical alarms analyzed and a protective factor (RR=0.32) regarding them.

Among the outcomes that emerge from these results, the most relevant is the possibility of offering quality and safety in the clinical surveillance of patients treated for AMI. Nurses are not with these patients at all times. For this reason, they need

the technology to be, in fact, allies, providing relevant data that influence decision making. It was verified, in the individualized parameterization, a rational way to use the resources of the monitor, promoting a better interaction "man-machine" to meet, more precisely, the needs of both the patient and the professional.

Further studies with different populations are suggested, whether using or not the ProPIAM protocol. They must try to create more data that can or cannot corroborate the findings of this study; they could also show the behaviors of other variables not followed here.

REFERENCES

1. Hu X, Sapo M, Nenov V, Barry T, Kim S, Do DH, et al. Predictive combinations of monitor alarms preceding in-hospital code blue events. J Biomed Inform [Internet]. 2012 [cited 2019 Mar 11];45:913–21. Available from: https://doi.org/10.1016/j.jbi.2012.03.001
2. Ibanez B, James S, Agewall S, Antunes MJ, Bucciarelli-Ducci C, Bueno H, et al. ESC scientific document group; 2017 ESC guidelines for the management of acute myocardial infarction in patients presenting with st-segment elevation: the task force for the management of acute myocardial infarction in patients presenting with st-segment elevation of the european society of cardiology (ESC). Eur Heart J [Internet]. 2018 [cited 2019 Mar 11];39(2):119–77. Available from: https://doi.org/10.1093/eurheartj/ehx393
3. Vanheusden LMS, Santoro DC, Szpilman D, Batista CO, Correia LFB, Cruz Filho FES. [Phase-dependent concept in cardiopulmonary resuscitation]. Rev. SOCERJ [Internet]. 2007 [cited 2017 Apr 15];20(1):60-4. Available from: http://sociedades.cardiol.br/socerj/revista/2007_01/a2007_v20_n01_art09.pdf Portuguese.
4. American Association of Critical Care Nurses. Practice alert outlines alarm management strategies [Internet]. [place unknown]: Evidence Based Practice Resources Work Group; 2013 [cited 2019 Mar 17]. Available from: https://www.aacn.org/newsroom/practice-alert-outlines-alarm-management-strategies
5. Ruppel H, Funk M, Whittemore R. Measurement of physiological monitor alarm accuracy and clinical relevance in intensive care units. Am J Crit Care [Internet]. 2018 [cited 2019 Mar 11];27(1):11-21. Erratum in: Am J Crit Care. 2018 Mar;27(2):123 Available from: https://doi.org/10.4037/ajcc2018385
6. Cvach M. Monitor alarm fatigue: an integrative review. Biomed. Instrum Technol [Internet]. 2012 [cited 2019 Mar 11];46(4):268-77. Available from: https://doi.org/110.2345/0899-8205-46.4.268
7. The Joint Commission Announces 2014 National Patient Safety Goal. Joint Commission Perspectives. 2013; 33(7): [about 3p.]. Available from: https://www.jointcommission.org/assets/1/18/JCP0713_Announce_New_NSPG.pdf
8. The Joint Commission. Sentinel event alert: medical device alarm safety in hospitals. Joint Commission [Internet] 2013;(5): 3 p. Available from: https://www.jointcommission.org/assets/1/18/SEA_50_alarms_4_5_13_FINAL1.PDF
9. AAMI: Advancing Safety in Medical Technology. Call Alarms. A Siren call for action: priority issues from the medical device alarms SUMMIT [Internet]. Arlington (VA): AAMI; 2011. [cited 2019 Mar 17]. 48 p. Available from: http://kami.camp9.org/Resources/Pictures/2011%20Alarms%20Summit%20Report.pdf
10. Coutinho ESF, Huf G, Bloch KV. [Pragmatic clinical trials: na option in the construction of health-related evidence]. Cad. Saúde Pública [Internet]. 2003 [cited 2018 Jun 08];19(4):1189-93. Available from: http://dx.doi.org/10.1590/S0102-311X2003000400039 Portuguese.
11. Drew BJ, Califf RM, Funk M, Kaufman ES, Krucoff MW, Laks MM, et al. American heart association; councils on cardiovascular nursing, clinical cardiology, and cardiovascular disease in the young. Practice standards for electrocardiographic monitoring in hospital settings: an american heart association scientific statement from the councils on cardiovascular nursing, clinical cardiology, and cardiovascular disease in the young: endorsed by the international society of computerized electrocardiology and the american association of critical-care nurses. Circulation [Internet]. 2004 [cited 2019 Mar 11];110(17):2721-46. Erratum in: Circulation. 2005 [cited 2019 Mar 11];111(3):378. Available from: https://doi.org/10.1161/01.CIR.0000145144.56673.59
12. V diretriz da sociedade brasileira de cardiologia sobre tratamento do infarto agudo do miocárdio com supra desnível do segmento ST. Arq Bras Cardiol [Internet]. 2015 [cited 2019 Mar 11];105(2):[about 121 p.]. Available from: http://publicacoes.cardiol.br/2014/diretrizes/2015/02_TRATAMENTO%20DO%20IAM%20COM%20SUPRADESNIVEL%20DO%20SEGMENTO%20ST.pdf
13. O'Gara PT, Kushner FG, Ascheim DD, Casey Jr DE, Chung MK, Lemos JA, et al. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: a report of the American college of cardiology foundation/American Heart Association task force on practice guidelines. J Am Coll Cardiol [Internet]. 2013 [cited 2019 Mar 11];61(4):e78-e140. Available from: https://doi.org/10.1016/j.jacc.2012.11.019
14. Armola RR, Bourgault AM, Halm MA, Board RM, Bucher L, Harrington L, et al. AACN Levels of Evidence: What's New? Crit Care Nurse [Internet]. 2009 [cited 2019 Mar 11];29(4):70-3. Available from: https://doi.org/10.4037/ccn2009969
15. McGrath SP, Taenzer AH, Karon N, Blike G. Surveillance monitoring management for general care units: strategy, design, and implementation. Jt Comm J Qual Patient Saf [Internet]. 2016 [cited 2019 Mar 11] ;42(7):293-302. Available from: https://doi.org/10.1016/S1553-7250(16)42040-4
16. Graham KC, Cvach M. Monitor alarm fatigue: standardizing use of physiological monitors and decreasing nuisance alarms. Am J Crit Care [Internet]. 2010 [cited 2019 Mar 11];19(1):28-34. Available from: https://doi.org/10.4037/ajcc2010651
17. Rayo MF, Mansfield J, Eiferman D, Mignery T, White S, Moffatt-Bruce SD. Implementing an institution-wide quality improvement policy to

ensure appropriate use of continuous cardiac monitoring: a mixed-methods retrospective data analysis and direct observation study. BMJ Qual Saf [Internet]. 2016 [cited 2019 Mar 11];25(10):796-802. Available from: https://doi.org/10.1136/bmjqs-2015-004137

18. Winters BD, Cvach MM, Bonafide CP, Hu X, Konkani A, O'Connor MF, et al. Technological distractions (part 2): a summary of approaches to manage clinical alarms with intent to reduce alarm fatigue. Crit Care Med [Internet]. 2018 [cited 2019 Mar 11];46(1):130-7. Available from: https://doi.org/10.1097/CCM.0000000000002803

19. Sowan AK, Gomez TM, Tarriela AF, Reed CC, Paper BM. Changes in default alarm settings and standard in-service are insufficient to improve alarm fatigue in an intensive care unit: a pilot project. JMIR Hum Factors [Internet]. 2016 [cited 2019 Mar 11];3(1):e1. Available from: https://doi.org/10.2196/humanfactors.5098

20. Farias CCP. Parametrização de alarmes de monitores multiparamétricos em unidade de cuidados intensivos traumato-ortopédicos: contribuições para minimização da fadiga de alarmes. [Dissertation on the Internet]. Rio de Janeiro: Universidade Federal do Estado do Rio de Janeiro, Centro de Ciências Biológicas e da Saúde;2015 [cited 2019 Mar 17]. 120 p. Available from: http://www2.unirio.br/unirio/ccbs/ppgenf/arquivos/dissertacoes-arquivo/dissertacoes-2015/carolina-correa-pinto-de-farias

21. Jacques S. Breaking barriers to patient-centric alarm management. Biomed Instrum Technol [Internet]. 2016 [cited 2019 Mar 11];50(3):181-3. Available from: https://doi.org/10.2345/0899-8205-50.3.181

22. Brantley A, Collins-Brown S, Kirkland J, Knapp M, Pressley J, Higgins M, et al. Clinical trial of an educational program to decrease monitor alarms in a medical intensive care unit. AACN Adv Crit Care [Internet]. 2016 [cited 2019 Mar 11];27(3):283-89. Available from: https://doi.org/10.4037/aacnacc2016110

23. Ryan KM, Gagnon M, Hanna T, Mello B, Fofana M, Ciottone G, et al. Noise pollution: do we need a solution? An analysis of noise in a cardiac care unit. Prehosp Disaster Med [Internet]. 2016 [cited 2019 Mar 11];31(4):432-5. Available from: https://doi.org/10.1017/S1049023X16000388

24. Bridi AC, Silva RC, Farias CC, Franco AS, Santos VL. [Reaction time of a health care team to monitoring alarms in the intensive care unit: implications for the safety of seriously ill patients]. Rev Bras Ter Intens [Internet]. 2014 [cited 2019 Mar 11];26(1):28-35. Available from: http://dx.doi.org/10.5935/0103-507X.20140005

25. Cosper P, Zellinger M, Enebo A, Jacques S, Razzano L, Flack MN. Improving clinical alarm management: guidance and strategies. Biomed Instrum Technol [Internet]. 2017 [cited 2019 Mar 11];51(2):109-115. Available from: https://doi.org/10.2345/0899-8205-51.2.109

26. Ketko AK, Martin CM, Nemshak MA, Niedner M, Vartanian RJ. Balancing the tension between hyperoxia prevention and alarm fatigue in the NICU. Pediatrics [Internet]. 2015 [cited 2019 Mar 11];136(2):e496-504. Available from: https://doi.org/10.1542/peds.2014-1550

27. ISO: International Organization for Standardization [Internet]. ISO 9241-11:2018. Ergonomics of human-system interaction -- Part 11: Usability: Definitions and concepts. [Internet]. 2018 [cited 2018 May 27]; [about 1 screens]. Available from: https://www.iso.org/standard/63500.html