Journal of Nursing
Revista de Enfermagem
UFPE On Line
ISSN: 1981-8963

ORIGINAL ARTICLE

SOUND PRESSURE LEVELS IN A PEDIATRIC INTENSIVE CARE UNIT

NÍVEIS DE PRESSÃO SONORA EM UMA UNIDADE DE TERAPIA INTENSIVA PEDIÁTRICA

NIVELES DE PRESIÓN SONORA EN UNA UNIDAD DE TERAPIA INTENSIVA PEDIÁTRICA

Margarida dos Santos Salú[1], Thiago Quinellato Louro[2], Tereza Tonini[3], Roberto Carlos Lyra da Silva[4], Nébia Maria Almeida de Figueiredo[5], Carlos Roberto Lyra da Silva[6]

ABSTRACT

Objective: to measure the sound pressure level emitted by electromedical equipment in the pediatric intensive care unit. ***Method:*** observational study, in which we proceeded to 10 measurements of the sound pressure level every 15 minutes in isolating the pediatric intensive care unit. After each SPL measurement, the alarm of 10 equipment, one for each measurement, was set off. Data were analyzed using descriptive statistics and presented in figures. The research project was approved by the Research Ethics Committee, CAEE: 05203412.9.0000.5285. ***Results:*** the average sound pressure level = 47,67dBA, standard deviation of 1.0089dBA and peak of 50,3dBA. After the subtraction of environmental sound pressure level with the Σ-environment equipment, median was of 23,75dBA, standard deviation = 10,187 and peak = 30dBA. The noise levels exceed recommendations of national and international organizations. The parameterization of the alarm may help decrease the pediatric intensive care unit. ***Conclusion:*** there is need to rethink this environment and establish strategies to reduce noise, making the PICU acoustically less uncomfortable. ***Descriptors:*** Nursing; Noise; Acoustics.

RESUMO

***Objetivo*:** medir o nível de pressão sonora emitido pelos equipamentos eletromédicos em unidade de terapia intensiva pediátrica. ***Método*:** estudo observacional, no qual procedeu-se 10 medições do nível de pressão sonora a cada 15 minutos no isolamento da unidade de terapia intensiva pediátrica. Após cada mensuração NPS ambiente, foi disparado o alarme de 10 equipamentos, sendo um para cada mensuração. Os dados foram analisados pela estatística descritiva e apresentados em figuras. O projeto de pesquisa foi aprovado pelo Comitê de Ética e Pesquisa, CAEE: 05203412.9.0000.5285. ***Resultados*:** média de nível de pressão sonora do ambiente =47,67dBA, desvio padrão de 1.0089dBA e pico de 50,3dBA. Após a subtração de nível de pressão sonora do ambiente com o ∑ ambiente-equipamento, a mediana obteve = 23,75dBA, desvio padrão = 10,187 e pico = 30dBA. Os níveis de ruídos excederam recomendações de órgãos nacionais e internacionais. A parametrização dos alarmes pode contribuir para diminuição da unidade de terapia intensiva pediátrica. ***Conclusão*:** existe necessidade de repensar esse ambiente e estabelecer estratégias para redução de ruídos, tornando a UTIP acusticamente menos desconfortável. ***Descritores*:** Enfermagem; Ruído; Acústica.

RESUMEN

***Objetivo*:** medir el nivel de presión sonoro emitido por los equipamientos electro-médicos en unidad de terapia intensiva pediátrica. ***Método*:** estudio observacional, en el cual se procedió a 10 mediciones del nivel de presión sonoro a cada 15 minutos en el aislamiento de la unidad de terapia intensiva pediátrica. Luego de cada medida NPS ambiente, fue disparada la alarma de 10 equipamientos, siendo una para cada medida. Los datos fueron analizados por la estadística descriptiva y presentados en figuras. El proyecto de investigación fue aprobado por el Comité de Ética e Investigación, CAEE: 05203412.9.0000.5285. ***Resultados*:** media de nivel de presión sonoro del ambiente =47,67dBA, desviación estándar de 1.0089dBA y pico de 50,3dBA. Después de la resta del nivel de presión sonoro del ambiente con la ∑ ambiente-equipamiento, la mediana fue = 23,75dBA, desviación estándar = 10,187 y pico = 30dBA. Los niveles de ruidos excedieron recomendaciones de órganos nacionales e internacionales. La parametrización de las alarmas puede contribuir para disminución de la unidad de terapia intensiva pediátrica. ***Conclusión*:** existe necesidad de repensar ese ambiente y establecer estrategias para reducción de ruidos, tornando la UTIP acústicamente menos desconfortable. ***Descriptores*:** Enfermería; Ruido; Acústica.

[1]Nurse, Unit for Critical Patients of Children's Hospital Ismélia da Silveira-HIIS/DC/RJ. Fiotec Scholarship in Clinical Research at Instituto Fernandes Figueira/FIOCRUZ. Master in Nursing, Graduate Program in Nursing, Federal University of Rio de Janeiro/PPGENF/Unirio. Rio de Janeiro (RJ), Brazil. E-mail: megsalu@yahoo.com.br; [2]Nurse, Professor, Nursing Department PURO/UFF. Doctoral Student, Graduate Program in Nursing and Life Sciences, Federal University of Rio de Janeiro/PPGENFBIO/Unirio. Rio de Janeiro (RJ), Brazil. E-mail: thiagolouro@hotmail.com; [3]Nurse, PhD Professor in Public Health, Coordinator of the Federal University of Rio de Janeiro/PPGENFBIO/Unirio. Rio de Janeiro (RJ), Brazil. E-mail: ttonini@terra.com.br; [4]Nurse, PhD Professor in Nursing, Coordinator of the Doctoral Course in Nursing and Life Sciences, Federal University of Rio de Janeiro/PPGENFBIO/Unirio. Rio de Janeiro (RJ), Brazil. E-mail: proflyra@gmail.com; [5]Nurse, Professor, PhD in Nursing - Fundamental Nursing Department, Federal University of Rio de Janeiro/UNIRIO. Rio de Janeiro (RJ), Brasil. Rio de Janeiro (RJ), Brazil. E-mail: nebia43@gmail.com; [6]Nurse, PhD Professor in Nursing, Coordinator of the Master's Course in Nursing and Life Sciences, Federal University of Rio de Janeiro/PPGENFBIO/Unirio. Rio de Janeiro (RJ), Brazil. E-mail: profunirio@gmail.com

INTRODUCTION

The pediatric intensive care unit (PICU) is configured, both in technological and human resources to assist, with the highest possible level of safety, patients aged between 29 days and incomplete 18 years old in need of intensive care. Its primary objective is to provide conditions for that child to remain alive and with possibilities to re-enter the social and family life, despite the possible consequences arising from complications inherent to their illness.

It is with a view to assisting the critically ill patient that we direct our attention to the child in a therapeutic environment, whose scenario is highly technified and leads us to reflect on the growing technological advance, which in turn, although collaborates with the recovery of critically ill patients, however, exposes more and more to the noises coming from the safety devices, either for their operation, or the sound of their alarm.

The result of this summation of sounds is called complex sound, which can be decomposed into multiple frequency tones, so it is possible to add pure tones, that is, sound waves of a frequency, which results in another wave, called complex.

The sound pressure levels (SPL) **L** correspond to a sound pressure **p** by the equation: $L = 10.\log (p/ p_0)^2 = 20.\log (p/ p_0)$, dB. Where: p_0 is the reference pressure of 0,00002N/ m^2, which is the value accepted as auditory threshold, while 200 N/m^2 matches the pain threshold. Respectively, their equivalent measures in decibels are zero (0) and 140dB.[1]

Not surprisingly to professionals in the intensive care, in many instances the noise levels measured in the ICU approach or even surpass those measured on roads where passenger cars in speed of 80 km/h and a distance of 15 meters may issue 0.2 N/m^2, which corresponds to approximately 70dBA. Therefore, depending on the exposure time, those who are in these units are more susceptible to health risks because exceeding the recommended levels.[1]

However, these SPL not also hinder communication, but also corroborate the loss of attention of professionals and, above all, irritability, fatigue, headaches, increased heart rate, blood pressure, promote peripheral vasoconstriction, increased secretion and mobility gastric, besides the contraction of the various segments and muscle groups.[1]

Since it is for professionals an important factor for hearing hygiene and therefore for their health, what to think about the health of pediatric patients, already battered, that is exposed to the SPL 24 hours a day? Such exposure may continue to the extent that the hospital stay in the PICU extends.

SPL, from 65dBA, are already enough to provide physiological effects, that is when the hypothalamic-pituitary-adrenal axis is sensitized in adults, culminating in the high secretion of epinephrine, norepinephrine and corticosteroids, resulting in increased blood pressure, changes in heart rate and peripheral vasoconstriction, and interfering with the assessment of sedation in critically ill patients.[3]

The purpose of this research is to measure the contribution of the sound pressure levels of 10 electromedical equipment in the production of noise in the PICU, of which were used: four different models of infusion pumps, three artificial ventilators, a BiPAP, a thermal blanket and a multiparameter monitor and, d. For this, we have the objective:

- To measure the sound pressure level emitted by electromedical equipment in the pediatric intensive care unit;
- To discuss their consequences for the acoustic comfort of pediatric patients.

METHOD

Ths was an observational study, carried out in a Pediatric Intensive Care Unit of a federal referral hospital for the care of maternal and child health located in the city of Rio de Janeiro. It is importat to note that, research is a part of the dissertation in progress of one of the authors in Master in Nursing Graduate Program/Master in Nursing at the Federal University of Rio de Janeiro/Unirio.

Data were obtained in from August 23 to 28, 2013, and entered into a database through the EPI-Info 3.5 and descriptively analyzed with statistical software Statistical Package for Social Sciences (SPSS) 17.0.

Results in minimum, medium and maximum values, standard deviation and median were calculated. To comply with the ethical requisites, the research protocol was approved by the Ethics and Research Committee of the institution, CAEE: 05203412.9.0000.5285 - Protocol No. 1228/PDS/2012 - UNIRIO/IFF.

The PICU used as scenery for this proposal has a collective area of 76,06 m^2 and has mixed characteristics, that is, consists of five common beds and a caution (isolation), all at the same collective area and in line with Resolution RDC 7 of February 24 2010 published by ANVISA. The location (isolation)

where measurements were carried out has 12,46m^2 (insulation + antechamber), as shown in Figure 1.

The nurses' station has a panoramic view of the beds, as it is in top front position to them. Not having a central monitoring, alarm settings can only be performed at the bedside. It has two access doors with manual lock. A door gives access to an anteroom to toilet. Then, another door has a direct connection to the PICU (antechamber of 2,43m^2). The floor is rubberized, suitable for hospital, which offers lower noise generation when moving furniture and walking on it.

The simplified sketch of the physical plan of the unit can be seen in Figure 1.

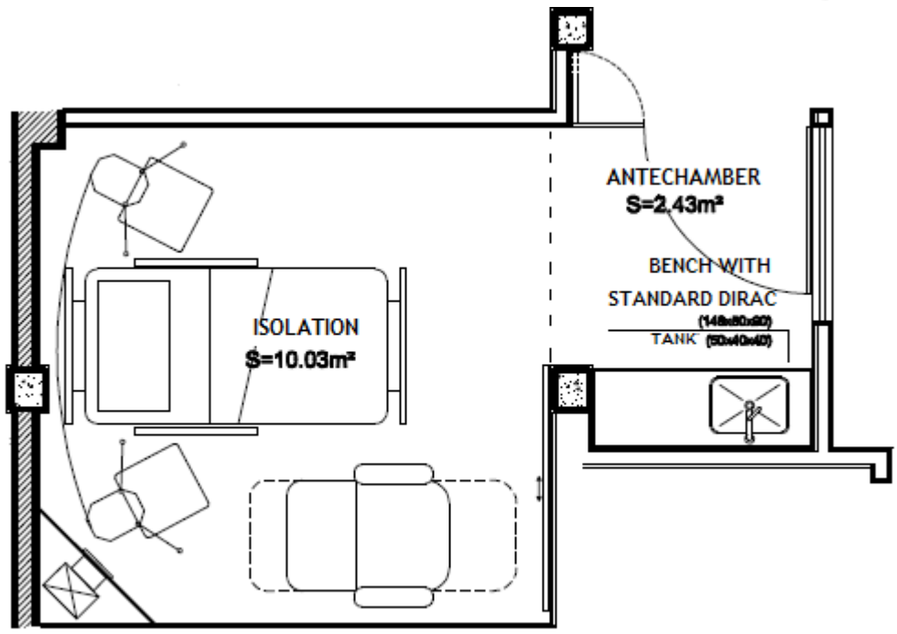

Figure 1. Layout plan of the PICU.

The PICU has several electromedical devices used as adjuncts to clinical and surgical approaches, including replacing and/or serving of advanced support of vital functions, such as the artificial ventilators staying at the bedside, thus emitting noise from their normal operation and their alarm. Along this important technological resource, many others contribute to the generation of noise and therefore the increase in sound pressure levels in the PICU environment, as it is the case of infusion pumps that are fixed in stative at the sides of the bed and multiparameter monitor located above the bed in the back (head).

It was used for NPL measurement purposes, the following equipment: one (1) peristaltic infusion pump - Hartmann – MiniMax make-Model: MM101; two (2) pediatric syringe pumps – Santronic make - ST670 ST670 ST680 models and lines ST690; one (1) infusion pump - B/Braun make - Infusomat compact model; one (1) artificial ventilator - BIRD make - model 8400 STi, microprocessor controlled electronic respirator of last generation, intended for adults; two (2) artificial ventilators - INTERMED make models - inter3 and inter3 plus neonatal and pediatric; one (1) multi-parameter monitor - NIHON KOHDEN make - BSM-4100J model / K - trade name: Life Scope P Bedside Monitor; one (1) BiPAP - make Philips Respironics - BiPAP Synchrony model, trade name: BiPAP autoSV; one (1) thermal blanket - 3M Bair Hugger make - model: 750, trade name: 3M Arizant Bair Hugger Patient Warming System 750.

The multidisciplinary team of the unit is composed of eight nurses distributed on day (DS) and night shifts (NS), 26 nursing technicians distributed in DS and NS, a doctor in charge, a doctor on duty every 8h, a routine doctor, four medical residents (2 R4 and R3 2) and two medical residents and interns and one physical therapist, totaling in the sector, more than 23 professionals during day shift and seven during the night shift. It is worth mentioning the presence of other professionals, not continuously, such as an occupational therapist, speech therapist, psychologist, radiology technicians and various experts, and the presence of family members and visitors of patients.

The sound pressure levels (SPL) were obtained with sound meter DEC-460 model, with measure in decibels (dBA), calibrated and manufactured according to the specifications of the International Electrotechnical Commission (IEC) number 60651, this reference adopted by the NBR 10152[4] of *Associação Brasileira de Normas Técnicas* (Brazilian Association of Technical Standards). The device was configured to operate in compensation circuit, track "A", as well as slow response (SLOW).

The measurements for the baseline were held in precautionary room (isolation), with the door and front flap closed and the decibel meter positioned one and a half meter height and with local equipment off. To measure the SPL of equipment, it was remained the same height with the distance from the generating source of one and a halt meter. This height matches to the recommended literature, 1m away from the ceiling.[4]

Before each measurement for equipment, we proceeded to measure the SPL of the aforementioned environment, and the value of SPL of the equipment was subtracted by the SPL found in the environment, reaching thus the real value of sound pressure level emitted by the equipment with triggered alarm.

It should be noted that it was not taken into consideration the sound propagation capacity, since it was not determined the removal of the tools (bed, equipment without using, etc.) present in basal measurement environment and that can act absorbing, reflecting or allowing the propagation of sound, however, the vessels were not a barrier between the sound level meter and the noise source, thereby the sound transmission occurred in the free field[5]. The wave front, the locus where the pressures are maximum, were not considered either, since the position of the noise generating equipment is not standardized, and may be changed several times, as is the case with infusion pumps and artificial ventilators, interfering, therefore, the pressure change (Ap) around atmospheric pressure at one point of the measurement area due to the contractions and expansions of the air.[5]

Samples were collected at night, since the human noises occur less intensity. All measurements were taken on the same night, with 15 minute intervals for each measurement (environment and alarming equipment), totaling 20 measures, 10 for the environment and 10 for alarming equipment.

RESULTS

The SPL of isolation ranged from 46,5dBA and 50,3dBA, averaging 47.67 dBA and standard deviation of 1,0089dBA. Figure 2 shows the change in sound pressure level found in isolation without the interference of the alarms of electromedical equipment used within that space, however, contaminated by noise from the common area of the PICU.

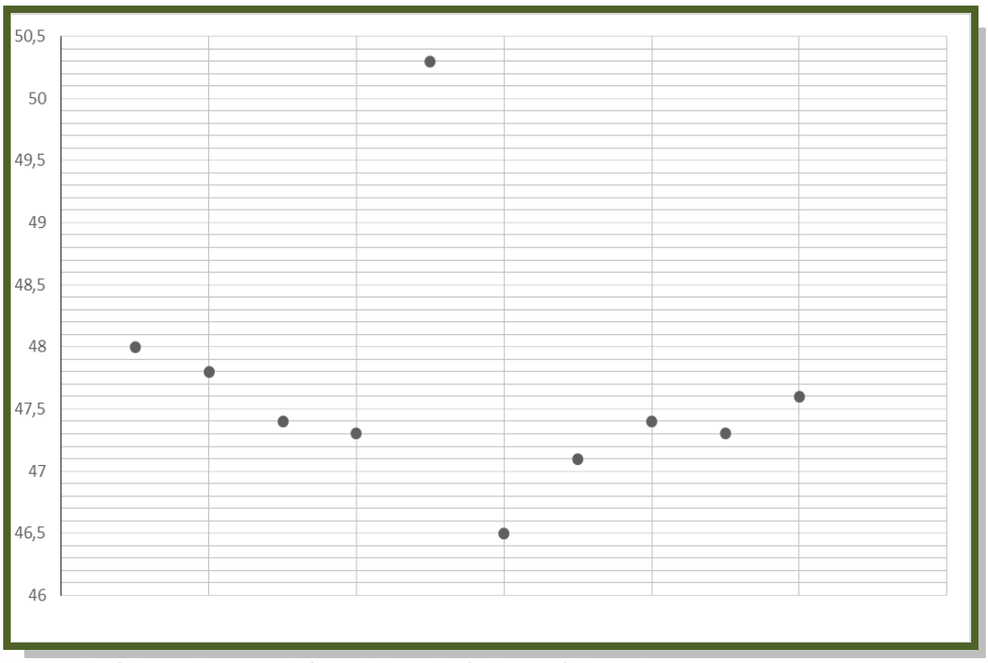

Figure 2. SPL environmental variation (isolation – $dBA_{env.P.}$).

The SPL ($dBA_{env.T.}$) of the Σ the alarm and environment varied between 48dBA and 78,6dBA, with mean 69,27dBA, median 71,45dBA, and standard deviation of 10,2788dBA. Figure 3 shows the change in sound pressure level after alarm triggering of each device, maintaining a predetermined time to measurement of values of 15 minute interval.

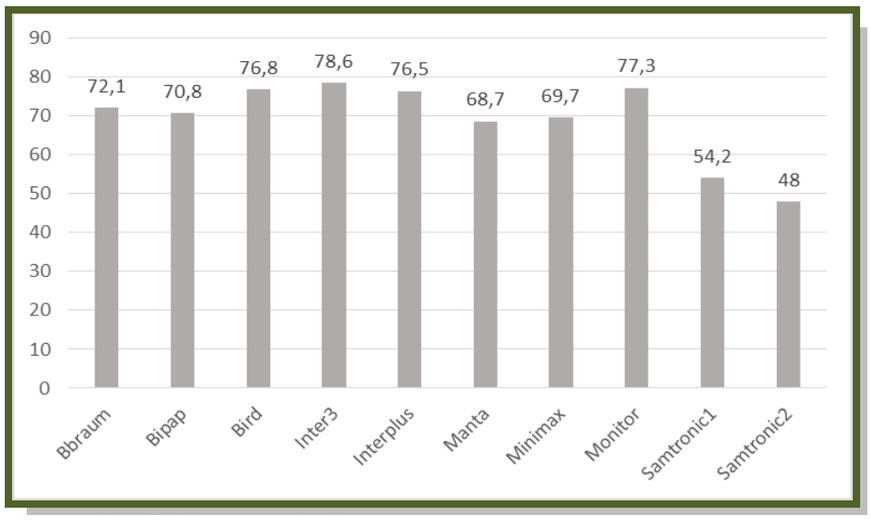

Figure 3. Σ SPL Alarme e Ambiente.

After the measurement of environmental values without alarm of electromedical equipment - $dBA_{env.P}$. (isolation without alarm) and of Σ environment-alarms - $dBA_{env.T}$, these values are subtracted from the measured value for SPL of each electromedical equipment - dBA_{equ}, so that it was possible a more accurate approximation to the "real" value sound pressure emitted by the alarm of each of the ten equipment selected, because environmental values were physically contaminated by external noise, therefore common to the environment of other spaces of PICU.

The SPL values of the equipment ranged from 0,6dBA and 30dBA, with mean of 21,6dBA and median of 23.75, standard deviation of 10,1874dBA. Figure 4 shows the variation in SPL of these medical devices.

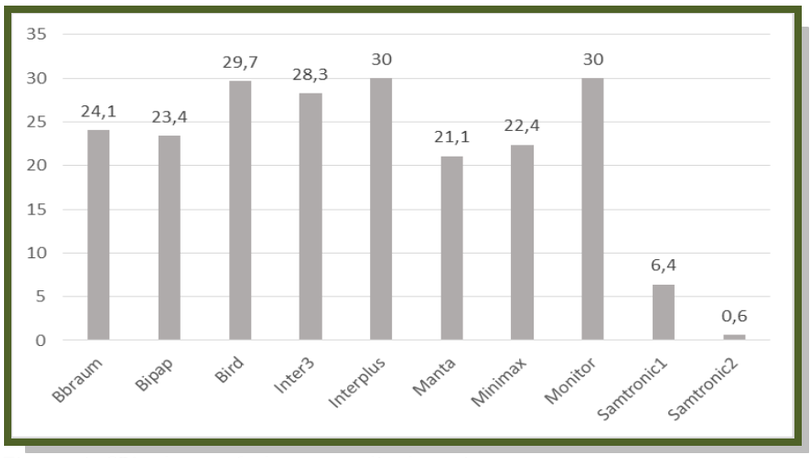

Figure 4. SPL alarm of electromedical equipment.

The contribution of alarms to the increase in sound pressure levels in the pediatric intensive care environment ranged from 1.3% to 64.5% and mean of 43.86%. Figure 5 shows the percentage change between the 10 medical devices used in this research.

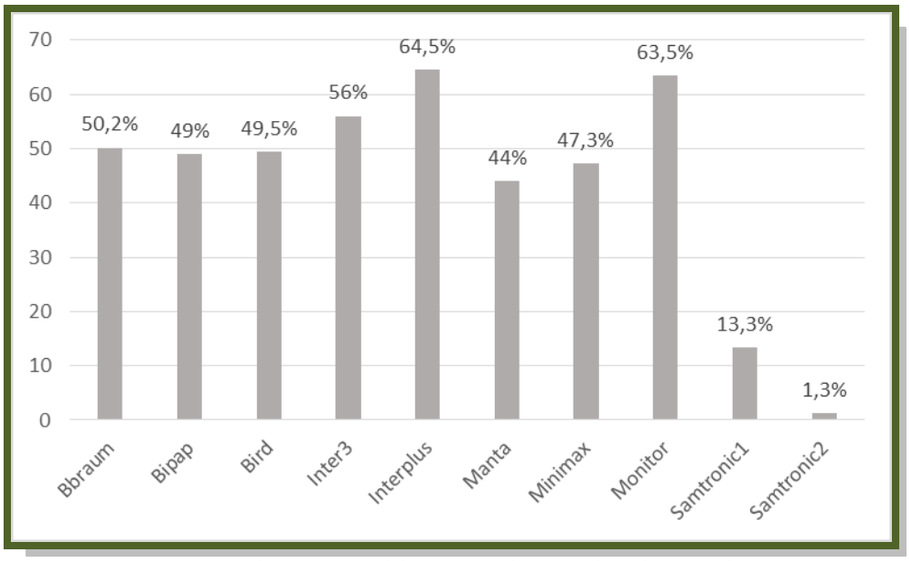

Figure 5. Percentage of increase of SPL according to the alarms of equipment.

DISCUSSION

Figure 1 shows that even in the condition of an isolation environment to assist the infants infected by multidrug-resistant bacteria and/or reverse isolation, its sound pressure levels are quite high for a closed environment, with its peak of 50.3dBA, minimum of 46.5dBA and mean of 47.67dBA, all above the levels recommended by the Agencies and Regulatory Standards, in Brazil and abroad.

Noise measurement studies in PICU show that SPL are above the levels accepted by the Environmental Protection Agency of the United States, which preconizes hospital levels of 45dBA for daytime and 35dBA for the night period.[3] In Brazil, the *Associação Brasileira de Normas Técnicas* (Brazilian Association of Technical Standards) (NBR10152) adopts a range from 35 to 45 dBA as acceptable SPL to different hospital environments, the first being the desirable level and the second, the acceptable limit.[4]

The American Academy of Pediatrics recommends that the amount of noise in pediatric and neonatal ICUs should not exceed the value of 45dBA[5], while the International Noise Council of the World Health Organization recommends no more than 40dBA for hospital indoors during the day, reducing from 5 to 10dBA for the night period.[5]

In Brazil, despite the fact that the *Agência Nacional de Vigilância Sanitária National* (Health Surveillance Agency - ANVISA) does not have noise regulations for PICU, the Secretariat of Health Surveillance features as proposal the Ordinance 466 of June 4, 1998, which is not yet in force. In this proposal, acceptable noise levels will meet than recommended by the International Council of Noise, in which it must not exceed 45 dBA during the day, 40dBA on evenings and 20dBA at dawn.[6]

When we add the noise from 10 electromedical devices, we identified that there was percentage change in sound pressure increase on the order of 1.3% to 64.5%, of which, the equipment that less contributed to the increase in SPL was Samtronic 2 pump, unlike the artificial ventilators Interplus, whose increase reached the order of 64.5% and the Inter 3 with 56%, followed by Multiparameter Monitor with 63.5%. It should be noted that the multiparameter monitors are the most used equipment in an intensive care unit, including pediatric.

All patients admitted to the PICU have their vital functions monitored by multiparametric equipment and many are dependent on artificial mechanical ventilation, so when it comes to a scenario with 5 beds in one collective area, only a multiparameter monitor and an artificial ventilator already alarming are enough to quantitatively increase the noise levels in the unit, it is clear that the values are different, because the collective space has an area six times larger than the area used for the observation and measurement of pressure levels. Figure 4 shows the percentage of increase of the ten electromedical devices used in this research.

In addition to the perspective of hearing comfort of pediatric patients, high and constant exposure to sound pressure levels in the PICU, besides causing physiological changes in the patient's body, also contributes to the Alarm Fatigue phenomenon.

This phenomenon was described by a nurse and has been studied seriously from the negative impact it has to health services, especially for patients in need of intensive care in the ICU. The ECRI Institute, an American non-profit organization that conducts research on good health practices, publishes a "top ten" annual dangerous technologies in health. "The danger of alarms" is the first of the ten cited in the 2012 list, including in this topic the improper configuration of the alarm, alarm fatigue, the modification of alarm patterns without restoration of the initial configuration and parameterization of alarm limits improper to patient needs.[7]

Results of a study using the scenario of a general ICU of a private hospital that evaluated the stress agents, potential causes of physical and mental disorders for inpatients, showed that verbal communication in high tones between the health team is configured as one of the stressors.[7] Thus, if we consider that, together with alarms, the conversations between the team will enhance the noise in the PICU. Even though the complete interruption of this process is impossible, nursing along with other team members must join for the sake of reduction of unnecessary noise.

The starting point could be the reduction of excess due to alarms triggered by such equipment, either by reducing the use of unnecessary electro-technical apparatus and/or the appropriate parameterization of its values according to actual need of the patient. Various studies show excess alarms in the ICU, which is the main cause of discomfort and alarm fatigue.[8]

As 80% -99% of the alarms are false positives or considered insignificant by the ICU team, it is possible a changing culture movement within these highly technified units aimed at reducing the number of trigger alarms of these equipment.

The most widely used equipment in the setting of intensive care and the second equipment that contributes most to the increase of noise in the PICU of this study are the alarms of multiparameter monitors, which already come from factories pre-configured on purpose with a high sensitivity to any physiological change of the patient. A multicenter study indicates that such equipment reach a sensitivity rate of up to 97%, however, its specificity is only 58%.[8,9] These results show that in many cases the multiparameter monitors sound their alarms without a clinical relevance compatible with the actual condition of the patient, that is, acoustic discomfort caused by the alarm is inversely proportional to its usefulness. In this case, alarms are unnecessary.

Given the above, it appears that the contribution of these alarms to increase the SPL in PICU is something worrying, mainly due to their unfavorable results regarding their overt consequences or not to the body of the child in need of intensive care, and that can bring serious consequences during and after hospitalization, ranging from difficulty of sleep and rest to even more serious cases such as anxiety, depression, hypertensive risks etc.[1] Therefore, it is of utmost importance the need to discuss, deploy and implement possible and practicable measures to reduce the SPL in PICU and watch the final outcomes.

The "Practice Alert" report, released in 2013 by the American Association of Critical-Care Nurses on the management of alarms, included different strategies based on evidence in order to reduce fatigue alarms and their deleterious effects. Among the interventions, the one that could most contribute to reducing the SPL in this scenario is the individualized parameterization of the minimum and maximum alarm limits. Its level of evidence was classified in stratum "C", which is the highest level of evidence.

It is emphasized that the educational program should be the first step to raise awareness of the work team as to the importance of maintaining an acoustically comfortable environment for the client, professionals and family, aimed at significantly reducing the SPL in order to minimize the deleterious effects of noise.[9]

Alarms still are important tools to aid the nursing professionals in the course of their activities in ICUs, prepared in order to alert them in the event when sudden changes of hemodynamic parameters occur, however, studies show that the vast majority of alarms triggered in these environments is false, causing the non-attending by the team, and likewise constitutes powerful disturbing of the customers' sleep. [10]

The change in medical intensivist culture with a view to individual parameterization of the alarm limits of electromedical devices used to monitor and/or serve as life support for a patient, that is, to define with more reliable criteria the minimum and maximum alarm limits for each physiological parameter measured, appears to be, for this problem, the strategic action that can contribute to the reduction of SPL in PICU and thereby improve, among other factors, the acoustic comfort of the little patients, optimizing their homeostatic capacity to experience the trinomial health team – electromedical equipment-environment.

CONCLUSION

This study is an experience that requires replication and a rigorous approach in the basal sound pressure item, given that the scenario used for the measurement of SPL coming from the alarms of 10 electromedical equipment was not an environment with acoustic insulation. However, the results point to a recurring concern for the environment/comfort, as pointed out in the Nightingalean axioms and which is gaining more and more space in the nursing research topics, including, in the research object condition.

Data shows that when the electromedical devices studied sound their alarms, they significantly increase the environmental SPL. SPL values measured with the trigged alarms, along with the noise of the research

environment scenario, exceeded the recommended levels by national and international official organizations.

Of the 10 equipment studied, artificial ventilators followed by multiparameter monitors are the equipment that most increased SPL on the scenery; however, they are the equipment most frequently used in intensive care. Therefore, it is believed that the establishment and implementation of a strategic plan based on proper individualized parameterization of the minimum and maximum levels of alarms of such equipment could generate change in culture for use and optimization of technological resources with minimal impact to the patient and positively impact the control and reduction of environmental noise, making it safer and more comfortable for those who experience intensive care and those who work in this scenario.

The nursing staff has an important role in this process, first of all, since they are in larger quantities within the unit and of course, because they are an important element in the proposition, deployment and implementation of strategies for improving environmental acoustic quality, whether by surveillance of the parameterization of alarms, whether for immediate intervention required when an alarm is sounded, identifying the cause and taking the necessary steps with a view to minimizing the frequency of clinically irrelevant alarms firing or of low clinical relevance.

It is imperative that all members of the PICU staff recognize that noise is a stressor for the child and that the speech sometimes "romanticized" of humanization of PICU should transcend also and mainly for environmental issues as an essential condition for acoustic comfort, still little practiced and undervalued in the intensive care environment. It is possible, indeed, to plan nursing care and medical care combining technology, hosting, comfort and respect for the patient.

The physical structure, as well as the technological apparatus of PICU, has to be (trans)formed in a working environment conducive to the practice of critical care without the patient satisfaction is an unattainable goal.

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Submission: 2014/05/06
Accepted: 2015/01/22
Publishing: 2015/02/15

Corresponding Address

Margarida dos Santos Salú
Av. Rui Barbosa, 716 – (UPG)
Bairro Flamengo
CEP 22250-020 – Rio de Janeiro (RJ), Brazil