OSJ | OPEN SCIENCE JOURNAL

RESEARCH ARTICLE

Evaluation of Sound Pressure Levels in a Pediatric Intensive Care Unit

Caroline de Araujo Mendes[1]*, Carlos Roberto Lyra da Silva[1], Luciane Velasque de Souza[1], Joice Alves Cabral[1], Luana Borges Dutra[1], Raphael Barreiros Neves[1], Andrea Garcia[1], Adriana Carla Bridi[2], Margarida dos Santos Salu[3], Natalia Barroso[4]

[1]Universidade Federal do Estado do Rio de Janeiro, Brazil
[2]Universidade do Estado do Rio de Janeiro, Brazil
[3]Instituto Fernandes Figueira/Fiocruz, Brazil
[4]Instituto Nacional de Estudos e Pesquisas Educacionais Anisio Teixeira,Brazil

*Corresponding author: Caroline de Araujo Mendes:carolrosacrystal@hotmail.com

Citation: Mendes C.A., Silva C.R.L., Souza L.V., Cabral J.A., Dutra L.B., Raphael B.N., Garcia A., Bridi A.C., Salu M.S., Barroso N. (2020) Evaluation of Sound Pressure Levels in a Pediatric Intensive Care Unit. Open Science Journal 5(2)

Received: 18th March 2020

Accepted: 21st April 2020

Published: 15th May 2020

Funding: The author(s) received no specific funding for this work

Competing Interests: The author have declared that no competing interests exists.

Abstract:

The objective of this study is to evaluate the noise levels from a pediatric intensive care unit of a federal hospital in Rio de Janeiro, to verify if it fits the limits recommended by the regulatory agencies and if there would be any difference in these levels by the morning and the afternoon periods aiming to improve the quality of nursing care for critically ill children. It's an observational, exploratory, quantitative study, organized in three steps: Parameters collection and decibel meter calibration using based data from Salú, et al (2015); Data collection of 40 hours' discontinued observation (from 8am to 4pm) in different days on a period of two months using two decibel meters; Data processing in an Excel's spreadsheet created for the database and data analysis, performed on Microsoft Office Excel 2010 and R software and organized into graphs and tables. The results showed that: 61% of the alarms corresponded to the mechanical ventilator; Bed E had the lowest standard deviation (SD = 2.945) and the highest median (69.5dBA).Even by removing the E bed from the analysis, there is a significant difference ($p < 0.001$) between the sound pressure levels. The median of the afternoon (28.2dBA) were higher than the morning one (26.1dBA); Mechanical fan and monitors generated higher sounds; the pediatric intensive care unit has considerably exceeded what is recommended by national and international noise organizations.

New studies must be made in order to improve the knowledge about the effects of these noises in the infants and it's given some suggestions to decrease the harm caused by noise like using earmuffs or earplugs on the children during hospitalization and acoustic materials on the construction of the PICU.

Keywords: Noise Monitoring, Noise levels, Intensive care, Pediatrics

Introduction

Intensive care units (ICUs) are perceived as places with strange equipment, incessant alarms, individuals who pass by the multidisciplinary team and excessive lightning. All of these factors contribute to patients' psychological and physical stress [1 -2]. Thus, in addition to the totally different context from the usual routine, patients admitted to the ICU are exposed to these countless factors, including noise, considered to trigger stress especially for the pediatric public[3].

The Pediatric Intensive Care Unit (PICU) is defined as the sector of care for patients from 29 days to 14 or 18 years old, as a limit being defined according to the institution's routines [4]. The effects of excessive noise levels in ICUs vary according to the age of the patient, negatively affecting physical, psychological and behavioral aspects, consequently delaying the recovery process. In children, acoustic trauma, physiological responses to stress and sleep deprivation can occur, which can lead to delirium states with confusion and disorientation. In neonates, it can result in clinical problems, such as apnea, bradycardia, nutritional deficiencies, changes in sound perception, hearing loss and abnormal growth [5,6,7,8,9,10,11].There are studies in the NICU that corroborates that noise acts as a stressor leads to some changes in infants, including increased heart rate, physiologic and behavioral instability, and hearing disorder. It is known after a lot of research during the years that lower-frequency sounds tend to induce less stress responses than high frequency sounds in newborns [12]. A study carried out in Colombia, when evaluating the level of continuous equivalent noise, also found higher noise values than those recommended. Critical noise effects in hospitals are sleep disturbances, increased heart rate, blood pressure, sleep deprivation, impaired immune function, irritability and interference with communication [9,13].Thus, ideally the sound events during the night should not exceed 40 dB indoors and during the day not exceed 35 dB in most rooms where patients are being treated or observed. There is still a highlight for greater attention to sound levels in intensive care units and operating rooms[13,14]. Still, according to internationals bodies, the amount of environmental noise in a pediatric ICU should not exceed 45dBA during the day for indoor hospital environments and 35dBA at night time [14,15,16,17,18,19].

Many studies have been published showing the average noise levels in neonatal intensive care units (NICU). Authors of a study carried out in Colombia identified in a sample continuously 20 days analysis a noise level ranging between 49-92 dB, which caused concern, since the levels to which the newborns and the team are exposed exceed the recommendations [20].

There is a study in an NICU in USA that stated, after reading several studies, that noise levels in the NICU often exceed the international recommendations, having prolonged sounds between 70-80dBA. This excessive auditory stimulation, beyond increasing heart rate, blood pressure, and respiratory rate can decrease oxygen saturation. It has also been suggested that may influence the cortisol levels and lower immunity [21,22,23,24,25,26,27]. Alarms of clinical relevance, if underestimated, can lead to complications regarding the patient's clinical conditions, compromising their safety. However, even linked to patient safety, alarms of medical assistance equipment (MAEs) contribute to the increase in Sound Pressure Levels (SPL) in the ICU, especially inconsistent alarms [28, 29,30].Like other studies demonstrated, the nursing process in the PICU is optimized under conditions where distractions and stress are minimized, however, in the presence of excessive noise, the care process is interrupted and prone to errors [31].

MAEs end up generating several constantly noises at different intensities. SPLs indirectly influence the patient's recovery since acoustic comfort is an important factor during hospitalization. Therefore, it contributes to the well-being of the patients who remains in intensive care units exposed to SPNs for a long time sometimes.Demonstrating how MAEs can influence the noise level in intensive care units, this study was carried out in an unoccupied room from a Neonatal Intensive Care Unit (NICU), whose objective was to relate the noise produced by mechanical ventilators. It was identified that all high frequency ventilators tested in the study and used for neonatal care, produced ambient sound levels above the current recommended safety limits. This fact compromises the environment's quality and causes adverse effects on newborns' admitted into the NICU health [32].Staying in the ICU for more than 48 hours is considered a risk factor for hearing loss. Some previous studies described the harmful effects of high NPSs in children hospitalized in the PICU and Neonatal Intensive Care Unit (NICU), among them, hypoxia, increased release of adrenocorticotropic hormone and adrenaline, increased heart rate, systemic vasoconstriction, pupillary dilation, elevated blood and intracranial pressure, increased oxygen consumption and caloric expenditure, which in the long term, can lead to a delay in weight gain [24,26, 33, 34].

At the PICU, there are several sources of sounds, including equipment alarms; pagers, phones, the heating, ventilation, air conditioning (HVAC) system, even the team and the parents talking. Specifically, the team felt that the sound generated by critical clinical care was not natural as it was necessary for the good care. Therefore, employees were more likely to alarm the villain than to take personal responsibility for their influence on the increasing levels of sound inside the unit7.Another study carried out in an ICU at John Radcliffe Hospital in Oxford (United Kingdom), used the four-bed compartment and found that the highest levels of noise originated in areas where team conversations generally occurred, such as the nursing station or the area where daily group discussions take place. They also identified that the loud sound originated from monitors and fans, located close to the patients' ears, and these alarms were $>$ 50 dB, within the frequency range considered disturbing for the patients, despite awakening the professionals' attention it causes discomfort for the patients [35].Thus, the objectives of the present study are to evaluate the noise level in a pediatric intensive care unit belonging to a federal hospital in Rio de Janeiro, considering that care technologies and Sound Pressure Levels imply the acoustic comfort of the pediatric public hospitalized in this hospital, we wondered whether the noise levels would be within the limits recommended by the regulatory agencies and if there would be any difference in the noise levels in relation to the morning and afternoon periods, aiming to improve the quality of nursing care for critically ill children.

Materials and methods

This is an exploratory, quantitative study, developed in a Pediatric Intensive Care Unit (PICU) in a federal institution of the city of Rio de Janeiro during the day.

The unit was chosen for its large number of technologies and human resources. It consists of 6 beds, 5 of which are in common use separated by “curtains” that allows customers' privacy. The nursing station is centrally arranged, with full visibility of the beds, in addition to good audibility of alarms. Another aspect that needs to be considered is that during data collection and observation, all the five beds were held with patients. The plant of the PICU can be observed in Figure 1:

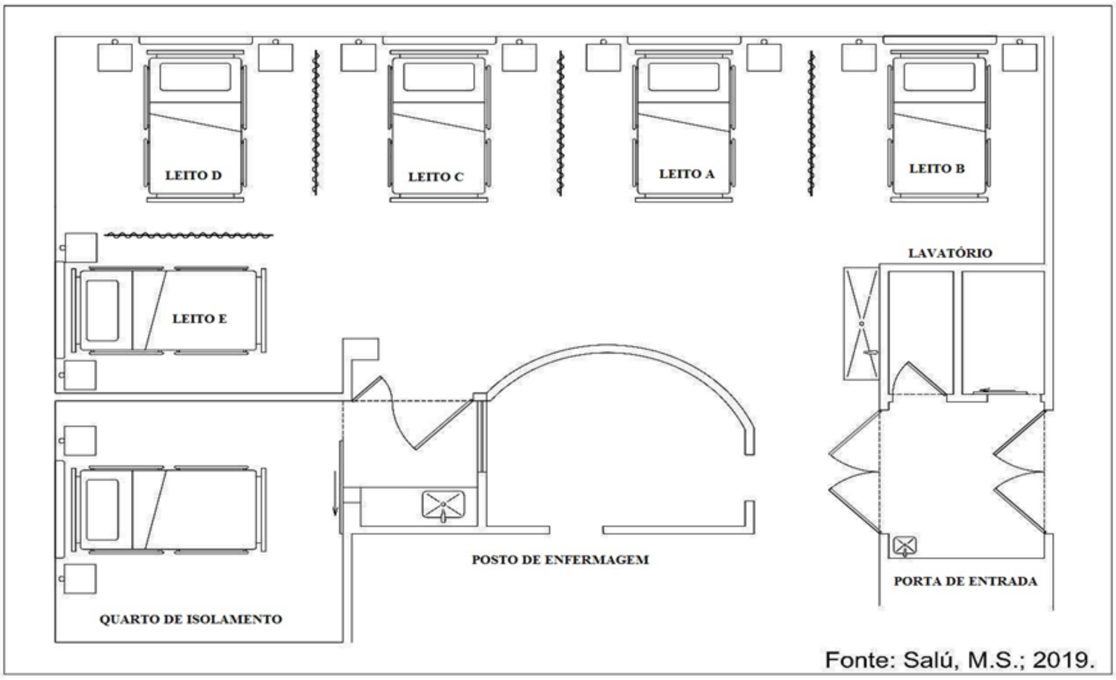

Figure 1 – Physical plant of the Pediatric Intensive Care Unit

As variables selected for the study we adopted: sound pressure levels, nursing station, patient's bed in the PICU and selected medical assistance equipment. The choice of variables occurred through the interest in investigating the influence of the sound pressure levels of the unit and the devices in relation to hospitalized patients.

The collection technique occurred through direct non-participant observation through a field diary. Data collection was performed by the responsible researcher, using two decibelimeters of DEC-460’s model, calibrated by the XP Service Company certificated by X0691.

One of the decibelimeters was fixedly placed at the nursing station and the other in the hospitalized patient's bed. The bed was rotated each day for collection, aiming to assess the Sound Pressure Levels (SPLs) inside the ICU, focusing on the noise generated by mechanical ventilators, multiparametric monitors and infusion pumps.

It is noteworthy that on all of the collected days the F bed, which would be the isolation bed, was not occupied, and due to its particularity, as it is a closed room, it was not included in this study.

Data Processing and analysis steps

1st: We created a table with the parameters in decibels (dBA) of medical-assistance equipment (EMAs) performed in an isolated room, with data from another study36. This study was carried out using the same equipment, from the same brand and in the same sector as the current study

2nd: Data collection: we took 40h (five days not followed from 8am to 4pm) of non-participant observation were carried out with notes in a field diary and measurement of the decibels generated through the decibel meters. Both were positioned in an upright position 100cm away from the walls and 90cm from the floor, one in the nursing station and the other in the patient's bed.

3rd: Data Treatment and Analysis: we created a database of decibel meter readings, using Microsoft Excel 2010. As for data analysis, we used the statistical software R to organize the data in tables and graphs.

The measurement of the equipment mentioned in the first stage can be seen in Table 1:

Table 1 - SPL values (dBA) of isolated medical assistance equipment

Electromedical Equipment	NPS
Santronic ST670 Pediatric Syringe Pump	6,4dBA
BBraun Infusomat Compact Infusion Pump	24,1dBA
Hartmann Peristaltic Infusion Pump - MiniMax - Model MM101	22,4dBA
Multi-parameter monitor NIHON KOHDEN - model BSM -4100 J / K	30dBA
INTERMED Inter3 Mechanical Fan	28,3dBA
Neonatal and pediatric INTERMED Inter 3 Plus Mechanical Ventilator	30dBA

To perform the statistical analysis we used the Shapiro-Wilk test to assess the normality of the sample, with a non-normal pattern being verified. After the result found, Wilcoxon's non-parametric tests (p-value <2.2e-16) were used for the shift variable and Kriskal Wallis (p-value <2.2e-16) for the local variable (bed and bed) of nursing). As a level of significance, $p < 0.05$ was adopted. Both demonstrated statistical significance.

Results

Through the notes of the field diary, it was possible to count during the 40 hours of observation the relative and absolute frequency of each alarmed EMA, which can be seen in Table 2:

Table 2 – Relative and absolute frequency of alarms of medical assistance equipment. Rio de Janeiro - RJ, 2019

Collection Day	Mechanical fan	Relative frequency(%)	Multi-parameter monitor	Relative frequency(%)	Infusion pump	Relative frequency(%)	TOTAL(f)
Day 1	29	18%	105	66%	25	16%	100%
Day 2	47	21%	137	62%	36	17%	100%
Day 3	89	32%	158	56%	33	12%	100%
Day 4	51	22%	132	57%	48	21%	100%
Day 5	8	5%	107	69%	39	26%	100%
TOTAL	224	21%	639	61%	181	18%	100%

Source: The authors, 2019.

Based on Table 2, among the observed EMAs the main source of noise generation was the multiparameter monitors, corresponding to 61% of the alarms, in second place it's the mechanical ventilator, corresponding to 21% and on the third position the infusion pumps, corresponding to 18%.

When viewing Figures 2 and 3, bed E presented the greatest difference between the minimum and maximum levels, compared to the other beds, presenting the lowest standard deviation (SD = 2.945) and the highest median (69.5dBA). This discrepancy in relation to the other beds may indicate a bias in the reading and interpretation of the data, leading to believe that this would be the reason why it was not possible to reach the recommended limits.

Bed E presented the biggest difference between minimum and maximum levels, compared to other beds. To rule out the possibility of bias, we performed a sensitivity test, excluding data from bed E as can be seen in Figure 3.

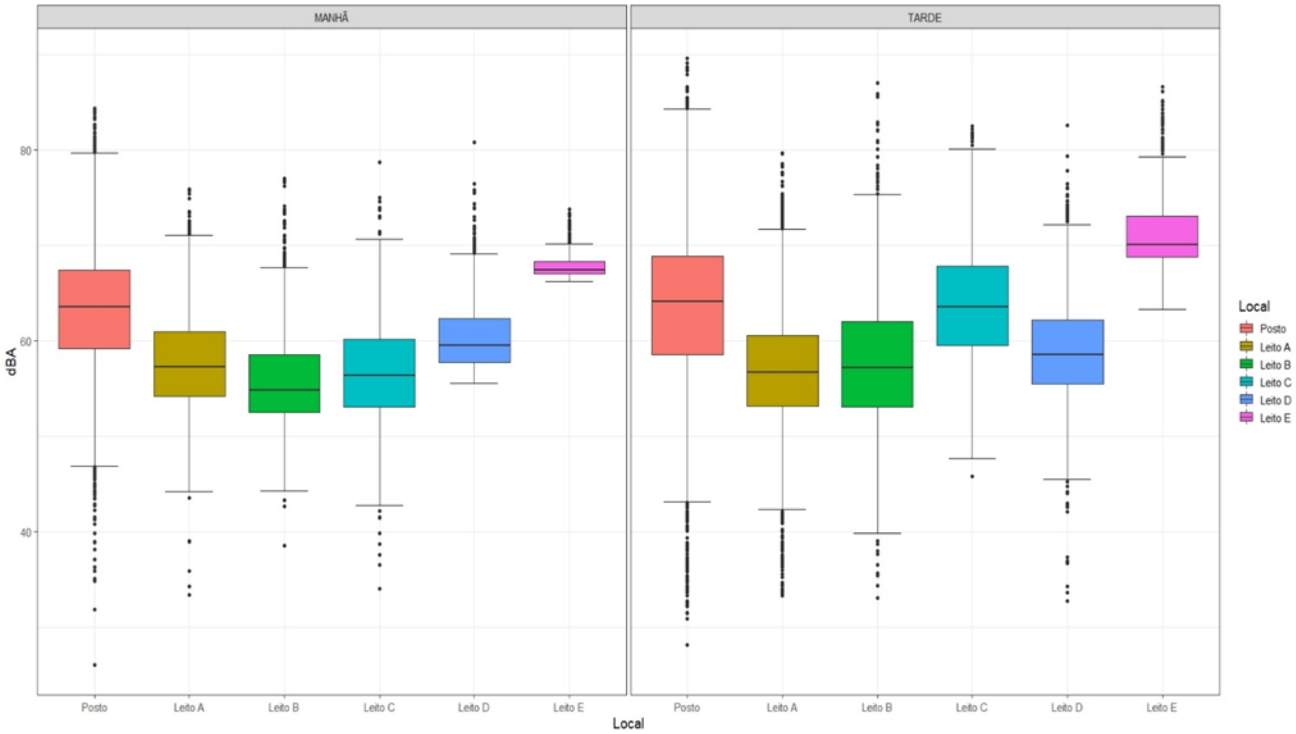

Figure 2 – Graph Sound Pressure Levels per bed of a Pediatric Intensive Care Unit (dBA). Rio de Janeiro / RJ, 2019. Source – authors 2019

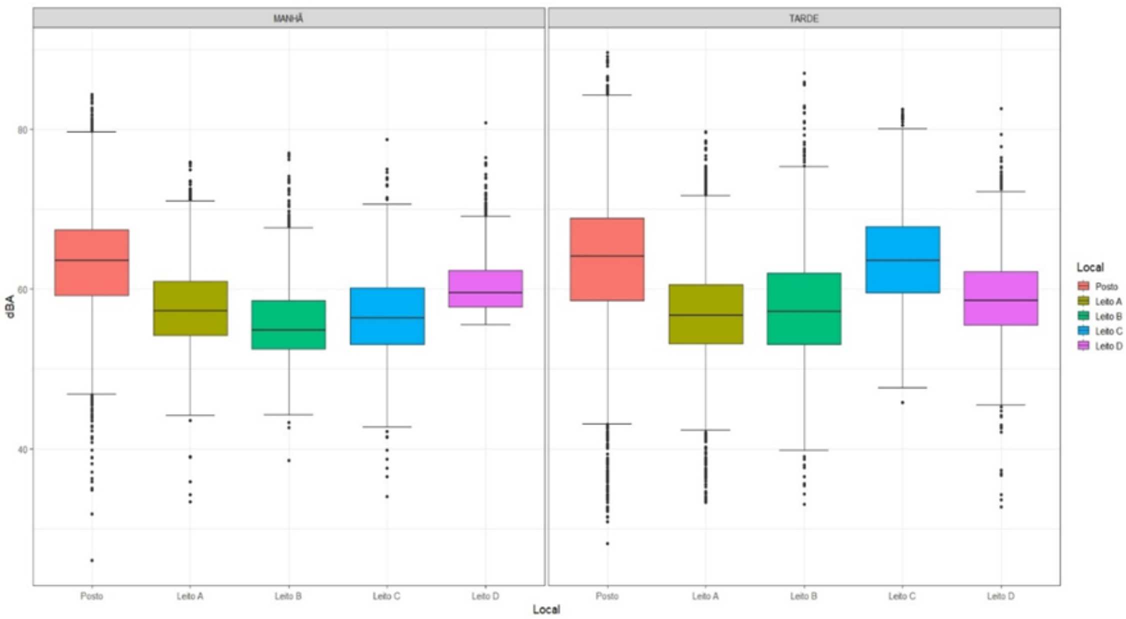

Figure 3 – Graph Sound Pressure Levels per bed of a Pediatric Intensive Care Unit (dBA) without bed E. Rio de Janeiro / RJ, 2019.

As shown in Figure 2 above and Table 3 bellow, the noise level in the studied environment showed a minimum value of 32.80 dBA in Bed D, corresponding to the fourth day of collection, and a maximum of 87 dBA in Bed B, corresponding to the first day collection.

Table 3 – Sound pressure levels (dBA) in occupied beds of a Pediatric Intensive Care Unit in the morning and afternoon. Rio de Janeiro - RJ, 2019

Bed	1st Quartile	3rd Quartile	Maximum	Minimum	Average	Median	Standard Deviation
Bed A	53,5dBA	60,7dBA	79,7dBA	33,5dBA	57,2dBA	56,9dBA	5,202364
Bed B	52,8dBA	61,1dBA	87,0dBA	33,1dBA	57,3dBA	56,6dBA	6,041769
Bed C	55,8dBA	65,3dBA	82,5dBA	34,1dBA	60,9dBA	60,7dBA	6,83796
Bed D	56,4dBA	72,8dBA	86,6dBA	32,8dBA	59,1dBA	58,8dBA	4,904562
Bed E	67,4dBA	72,8dBA	86,6dBA	63,3dBA	69,9dBA	69,5dBA	2,945284

Source: The Authors, 2019

Table 4 shows that in the morning we obtained an average noise level of 62.17dBA, while in the afternoon we can see that these levels were 62.55dBA. Another data that validated our finding was that the median of the afternoon (28.2dBA) was higher than that of the morning (26.1dBA). As for the standard deviation, there is a significant difference between the two shifts ($p < 0.001$).

We can also state that, comparatively, by including and excluding bed E, there is a significant difference ($p < 0.001$) between the sound pressure levels (SPL) generated between shifts.

Table 4 – Sound pressure level (dBA) x Location x Shift. Rio de Janeiro - RJ, 2019

		Average	DP	1Q	Median	3Q	P-valor
TIME	Morning	62.17	6.117.584	9.5	26.1	57.6	<0,001
	Afternoon	62.55	7.398.313	11.9	28.2	56.8	
	Morning without bed E	6.160.130	6.129.332	26.1	57.2	61.5	<0,001
	Afternoon without bed E	6.138.915	7.109.291	28.2	56.0	61.1	
LOCAL	Station	6.351.249	6.564.999	58.9	63.9	68.2	<0,001
	Bed A	5.721.321	5.202.364	53.5	56.9	60.7	
	Bed B	5.736.085	6.041.769	52.8	56.6	61.1	
	Bed C	6.096.084	6.837.960	55.8	60.7	65.3	
	Bed D	5.918.328	4.904.562	56.4	58.8	62.2	
	Bed E	6.990.921	2.945.180	67.4	69.5	72.8	

Source: The Authors, 2019

When organizing the data collection by time, we can see in figure 4, complementing with tables 5 and 6, that the nursing station on the fifth day of collection, corresponding to Bed E, was the one exceeding the maximum recommended limits of 45dBA. Table 5 shows that almost 100% of the time, the levels exceeded the limits.

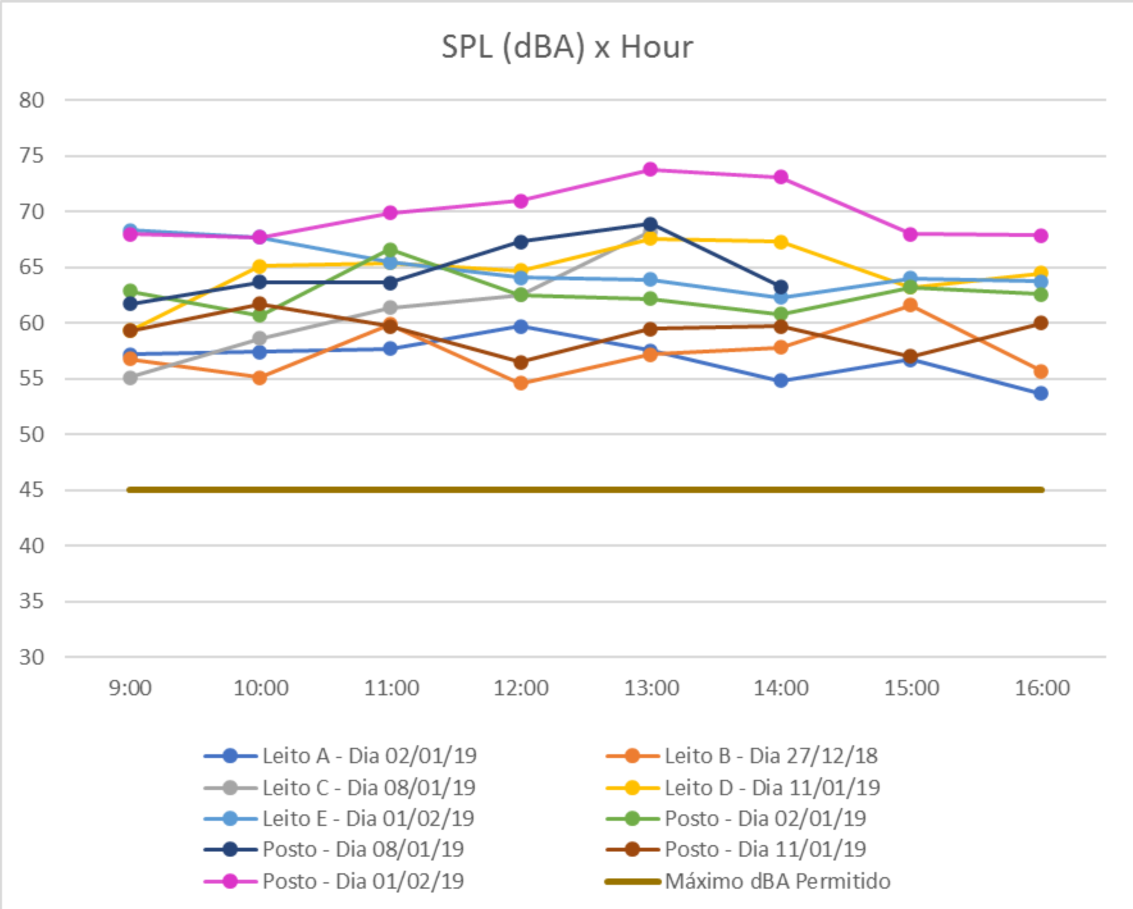

Figure 4 - Sound Pressure Level (dBA) graph of a Pediatric Intensive Care Unit x Hour. Rio de Janeiro - RJ, 2019.

Table 5 – Noise level count. Rio de Janeiro - RJ, 2019

	Account Noise Level								
Local	Bed B	Bed A	Bed C	Bed D	Bed E	Post Day 02	Post Day 03	Post Day 03	Post Day 04
>45	7329	22223	5447	12542	25016	28133	17789	5438	7104
<=45	30	96	12	15	0	132	0	15	0
Results within the limit	0,41%	0,43%	0,22%	0,12%	0,00%	0,47%	0,00%	0,28%	0,00%
Factor time between collection(s)	4	1	3	5	1	1	1	5	4
Data Converted into time(s)	120	96	36	75	0	132	0	75	0

Source: The Authors, 2019.

Table 6 - Sound Pressure Level (dBA) x Hour. Rio de Janeiro - RJ, 2019

		NPS X Hour								
Maximum dBA Allowed	Hour	Bed B 12/27/18	Bed A 01/02/19	Bed C 01/08/19	Bed D 01/11/19	Bed E 02/01/19	Post 01/02/19	Post 01/08/19	Post 01/11/19	Post 02/01/19
45	9:00am	56,80	57,20	55,10	59,30	68,32	62,90	61,70	59,30	68,00
45	10:00am	55,10	57,40	58,60	65,10	67,72	60,70	63,70	61,70	67,70
45	11:00am	59,90	57,70	61,40	65,40	65,48	66,60	63,60	59,70	69,90
45	12:00pm	54,60	59,70	62,50	64,70	64,06	62,50	67,30	56,50	71,00
45	1:00pm	57,20	57,50	68,20	67,60	63,93	62,20	68,90	59,50	73,80
45	2:00pm	57,80	54,80		67,30	62,31	60,80	63,30	59,70	73,10
45	3:00pm	61,60	56,70		63,20	64,01	63,20		57,00	68,00
45	4:00pm	55,70	53,70		64,50	63,75	60,60		60,00	67,90

Source: The Authors, 2019.

As shown in Table 6, since the beginning of the data collection, the NPS of the service station were above 45 dBA, varying between 59.3 and 73.8 dBA, and the times with the highest peaks were between 10am and 2pm. As for the bed, the highest peak was at 09am (68.32dBA). Overall, 0% of the time collected managed to stay within the maximum limit.

Discussion

It is important to highlight that the largest number of studies on sound levels has a focus on Neonatal Intensive Care, confirming the relevance in terms of conducting research in a Pediatric Intensive Care Unit.

Despite the international recommendations of sound levels, several studies presented existing analyses of the acoustic environment in the NICU that indicates that the noise standards are being exceeded regularly. Some studies from separate NICU environments have demonstrated that the average noise levels range from 48 to 55 dBA and 53.9 to 60.6 dBA. Our findings presented similar results and conclusions [23,37,38].

There is a study in a NICU that documented the effects of high noise levels. As short-term effects, they found increased physiologic stress in neonates. Even a brief stimulation from alarms and telephones can cause bradycardia and hypoxic episodes. As long-term effects they included hearing loss, language difficulties and altered brain development [26,27].

The present study, as shown in Table 2, points out that in 40 hours of observation 639 monitoring alarms were registered and 405 coming from mechanical ventilators and infusion pumps. There was a similar study that occurred in an adult ICU, with the same time of observation that had similar results; therefore we can infer that in both cases, the medical assistance equipment (EMAs) and the monitors are one of the main sources of alarms [29].

Also, the same findings were discussed in a study made in USA after using a level dosimeter in a PICU that stated that alarm sounds were the major environmental noise contributor and medical equipment noise was the second highest31. Recent studies stated that equipment alarms from monitors, infusion pumps and ventilators, as well as voices of staff members, consultants and families are the principal noise factors that contribute to the highest noise levels in the patient care rooms. Although equipment alarms likely contribute significantly to noise pollution, it is not an easily modifiable source in the PICU [39,40].

There is a study that during the measurements made in the four-bed ICU divided the sources of the highest recorded noises: the perfusor alarm (81 dBA); the nebulizer (80 dBA), monitor alarms (78,6 dBA),ventilator alarms (71,6 dBA), pulse oximeter alarms (71,2 dBA), and infusion pump alarms (68 dBA). By the results, we can see how the monitor and the ventilator can have a bad influence on the noise levels in the PICU, and unfortunately, in our study, the monitor was the first highest source of noise and the ventilator the second, respectively [41].

There are some authors that also mention that the alarms of the electromedical equipment that most produce noise usually are those from infusion pumps, multiparametric monitors, mechanical ventilators, pulse oximeters, among others [42].

Our study corroborates with another recent Brazilian study made in an adult ICU, in which it was found that the physiological variables that most triggered alarms in the services were heart rate and oxygen saturation28.In our study, through our field diary, it was possible to verify that of the 639 alarms coming from the monitor 435 (68%) were due to a drop in saturation and 204 (32%) were due to changes in heart rate.

Given the fact that the combined noise emitted from the necessary life support equipment, like ventilators and monitors, does not meet standards even without additional noise introduced by staff, visitors, or maintenance. Our study leads to the same direction. Therefore, it has become a necessity to start making efforts to investigate further about this problem and try to create strategies that allow the PICU and NICU to obtain the noise levels in an acceptable limit without compromising the assistance [40].

Some studies highlight that the high number of monitoring alarms and other equipments contributes by making the environment stressful, increasing the occupational risks of professionals and impairing the rest of hospitalized patients, increasing their length of staying and the use of sedatives, analgesics and anxiolytics [28,43,44,45].

Some researchers suggested in their studies some measures to be taken to reduce the sound pressure level inside the ICU such as: the adoption of quieter alarms, especially at night; the creation of different categories of alarms; the periodic analysis of the ICU acoustic profile; the review of the equipment used; the control of bells, alarms, cell phones, pagers, televisions and radios; the implementation of a continuing education program for professionals working in the ICU; the use of floor, ceiling and walls that absorb noise, divisions between the beds in the larger units, rubber seals on doors and windows and assessing noise levels before purchasing equipment, among other measures [18,46].

Figure 2 shows that the noise behavior in the nursing station and in beds A, B, C and D are quite similar. It was proven that despite the disagreeing of bed E, regarding the generation of noise, it does not represent a bias in the interpretation of the data, since the p value remained unchanged ($p < 0.001$).

These beds have a median noise level equal to or less than 60 Decibels (dBA), that is, in at least 50% of the measurements, a value less than or equal to 60 dBA was found. The E bed noise median was much higher, approximately 70 dBA. As can be seen in Figures 2 and 3, the median noise level is very similar, between approximately 60dbA and 90dBA, however, the noise variation in the afternoon shift is greater than in the morning one.

An additional study found that sound levels exceeded the recommended standard more than 70% of the time, while another found that noise levels only met recommendations 5.51% of the time. Those results make us realize that the acoustic comfort on the PICU and NICU is a serious and worrying matter to attend [33,47].

There is a study made in a NICU which the levels of acoustic events were compared to the acoustic level that was exceeded 50% of the time. The alarm noises were examined and determined to have peak levels that ranged between 82 and 86 dBA. In the same study two environments were investigated, the open-bay and the single-room where was confirmed that noise standards are not being met in the modern NICU. In fact, during the hours of acoustic recordings collected for this study, the noise level was never measured at or below 45 dBA in either room [40].

This study aimed to evaluate the effects of earmuffs use on the psychological and motor responses of premature infants and as a result, the infants that wore the earmuffs had significantly higher mean arterial oxygen saturation, the less frequent motor response and a decrease in their pulse and respiratory rate. That could be another suggestion on the present study to reduce the harm on acoustic comfort of the patients in the PICU48.

Although noise pollution was expected to be present in thePICU, it was unexpectedly high. According to this American study, the minimum hourly sound levels in either all areas or in occupied patient bed spaces showed medians of 47.5 and 48.0 dB, respectively. The results allow us to show the difficulty that the PICUs have on attaining to the recommended standards of noise and collaborate with our own results [49].

There is a study that focused on the effects of noise on the psychosocial work environment as a way for the noise reduction where the most prominent positive effects of improved acoustics were found on the afternoon shift. This result showed that even with the most noise due to family visits, with some strategies the harmful effects of noise can be reduced [50].

Figure 4 and tables 5 and 6 shows that both, the bed and the post, on all collected days have a minimum percentage where the maximum limit of 45dBA has been reached. The findings on these studies collaborate with our results that the noise pollution in pediatric intensive care units (PICUs), has sound levels often above recommended thresholds. However, the strategies used on other studies couldn't successfully reduce noise levels in a PICU by refining human behavior to create quieter patient bed spaces [47, 50, 51, 52, 53].

Researchers have indicated that noise levels in PICUs reach up to 100–120dBA, which is much higher than the international standards [54,55,56,57].

Another study in 2017 in the USA, appointed no improvement in that matter, having noise levels markedly higher than recommended at baseline and remained higher than recommended for all shifts. Another study also in the United States of America (USA) on 2000, shows that most NICUs have sound levels higher than those recommended levels [39,54].

One aspect that needs discussion as we could see in other studies, including ours, is the difference between the noise levels during shifts, morning and afternoon. Our study can be corroborated by another study that showed the same results. The mean levels of noise in the four-patient ICU were 72,1 dBA during daytime, 64 dBA in the evenings and 60 dBA at night. In the single-patient ICU rooms, the mean levels were 56 dBA during daytime, 54 dBA in the evenings, and 53 dBA at night. The peak levels of noise in the four-patient ICU were 91 dBA during daytime, 88,3 dBA in the evenings, and 84,3 dBA at night. Those data only confirmed the findings in our study that the noise levels are higher than recommended [41].

There is a similar study that consisted of sound level measurements and observation in a PICU and NICU during a 24h shifts during the week days and the researchers stated that the sounds were thought to be higher during the day when compared with evenings [7].

Since we had results similar from other researchers, we can state that our finding is in line with other studies like this one that showed a slightest reduction during morning shift. The morning shifts may have lower noise levels because of bedside rounds and the number of providers present in the NICU during this shift [39].

There is a study from 2016 remarkably similar to the present one in which they have used the same decibelimeter (DC-460) to measure the levels of continuous noise and the same international organizations as reference values of noise control. The evaluations were performed in three periods: morning (from 7am to 9am), afternoon (from 1pm to 3pm) and night (from 6pm to 8pm). As for the results, the researchers realized that the intensity of continuous noise might vary according to shifts, and all shifts showed noise above acceptable levels. These findings, alongside ours, only prove that maintaining the noise levels in the NICU and PICU within the recommended standards are a global challenge [15,19,58,59].

There is a brazilian study from 2015 made in a PICU, that showed results similar to this one. The sound pressure levels varied between 47.70 dB (A) and 70.00dB (A), with a general average of 60.67dB (A) and at dawn there was a small noise reduction, but insufficient to reach the levels appropriate. This data can demonstrate that the environment itself is routinely noisy, even without the interference of the variable number of people in the place60. To complement the information given to us by the researchers, there is also another brazilian study from 2013 that states that most of the noise in the PICU may be due to alarm devices, central air conditioner and also usual activities such as walking around the unit or touching objects [2].

The increasing technological advancement in health units ends up generating a need on the part of managers, to reflect on the importance and influence from the usability of the equipment available for a safe and quality assistance. Therefore, professional qualification through continuing education helps nurses and doctors to master the technological language and, consequently, enables assistance to occur with the minimum of complications and obstacles [60,61].

Other viable suggestions from researchers are changing the position of the medical alarms from the rooms to the nursing station and the use of soft ear plugs and eye masks to minimize sleep disturbances. The medical equipment such as intravenous pumps should be modified or renewed to reduce background sounds. There is a group of American researchers that stated that "it is unacceptable for machines to be positioned just behind the patient's head and produce high noise levels and loud alarm signals" [31,62,63].

Some suggestions were found in some studies for reducing sound levels, like: placing visible reminders to help staff lower their voices; think of options to reduce the equipment's alarms without compromising care; having an enclosed nursing station with centralized monitoring; having a separate enclosed unit entrance and transform the PICU into single-room design. The change of an open-bay unit to a single-family room design in a US PICU demonstrated a reduction in sound levels from 72 to 56 dBA[7,41,60,64].

Conclusion

During the construction of this article and after reading several papers, it came to our perception that there also appears to be a lack of literature regarding the immediate and long-term effects of exposure to high sound levels in neonatal and pediatric populations.

This demonstrate that there is a need for further research regarding the possible short and long-term effects of exposure to high sound levels in neonatal and pediatric critical care environments and this study can collaborate with a better neonatal and pediatric assistance, with the highlight on the importance of acoustic comfort from this populations during hospitalization.

After all the considerations made, it is essential that other studies on the subject and the hospitals themselves create strategies within their team to try to reduce noise in the PICU and the NICU during the shifts, taking into consideration the routine and the noise levels recommendations.

Based on several studies and considering the importance of creating a more safe PICU for the children hospitalized, we can see that through simple strategies and correct dissemination of information, it is possible to provide a more peaceful and conducive environment for the recovery of patients in the units of intensive care, as well as a better work place.

Thus, it is our desire that after all the information that have been discussed through this work, this study findings should be taken into account as an inspiration for new studies that may help creating strategies to protect the acoustic comfort of this public and as a way of improving nursing on pediatric intensive care.

References:

1.Bosch-Alcaraz A, Falcó-Pegueroles A, Jordan I. A literature review of comfort in the paediatric critical care patient. J. of Clinical Nurs [internet]. 2018 [last accessed on 2019 oct. 2]; 27(13-14):2546-2557. Available from: https://doi.org/10.1111/jocn.14345.

2.Oliveira F, de Paiva MB, Nascimento MAdeL, Rezende VM, da Silva AS, da Silva CRL. Nível de ruído da unidade de terapia intensiva pediátrica: estudo observacional correlacional. Braz. J. Nurs [internet]. 2013 set. [last accessed on 2018 apr. 12]; 12(2):431-441. Available from: http://www.objnursing.uff.br/index.php/nursing/article/view/4043.

3.Hamze F, Souza CC, Chianca TCM. Influência das intervenções assistências na continuidade do sono de paciente na unidade de terapia intensiva. 2015 [last accessed on 2018 apr. 13]. Available from: http://www.scielo.br/pdf/rlae/v23n5/pt_0104-1169-rlae-23-05-00789.pdf.

4.Anvisa (BR). Resolução n 7, 2010 fev. 24: dispõe sobre os requisitos mínimos para Unidades de Terapia Intensiva e dá outras providências. Brasília: Anvisa; 2010.

5.Basner M, Babisch W, Davis A, Brink M, Clark C, Janssen S, et al. Auditory and non-auditory effects of noise on health. Lancet. 2014; 383(9925):1325-1332. doi:10.1016/s0140-6736(13)61613-x.

6.Cardoso SMS, Kozlowski LC, Lacerda AB, Marques JM, Ribas A. Newborn physiological responses to noise in the neonatal unit. Braz J Otorhinolaryngol. 2015; 81(6):583–588. doi:10.1016/j.bjorl.2014.11.008.

7. Disher TC, Benoit B, Inglis D, Burgess SA, Ellsmere B, Hewitt BE, et al. Striving for Optimum Noise-Decreasing Strategies in Critical Care: Initial Measurements and Observations. J Perinat Neonat Nurs. 2017; 31(1):58-66.

8.Gadeke R, Doring B, Keller F, Vogel A. The noise level in a children's hospital and the wake-up threshold in infants. Acta Paediatr Scand. 1969; (58):164–170.

9.Galindo APG, Caicedo YC, Pereira AMV. Nivel de ruido en la unidad de cuidado intensivo adulto: Medición, estándares internacionales e implicancias sanitarias. Universidad Y Salud. 2015; 17(2):163-169.

10.Kudchadkar S, Aljohani O, Punjabi N. Sleep of critically ill children in the pediatric intensive care unit: a systematic review. Sleep Med Rev. 2014; 18(2):103–110. doi:10.1016/j.biotechadv.2011.08.021. [Secreted].

11.Smith HAB, Fuchs DC, Pandharipande PP, Barr FE, Ely EW.Delirium: an emerging frontier in the management of critically ill children. Anesthesiol Clin. 2011; 29(4):729–750. doi:10.1016/j.anclin.2011.09.011.

12.White-Traut RC, Nelson MN, Silvester MJ, Patel M, Lee H, Cimo S, et al. Maturation of the cardiac response to sound in high-risk preterm infants. Newborn Infant Nurs Rev. 2009; 9:193-9.

13.Berglund B, Lindvall T, Schwela D. Guidelines for community noise [internet]. 1999. Available from: http://www.moa.gov.cy/moa/environment/environmentnew.nsf/69D658BCCDE2FDB5C2258041002D 61F5/$file/Guidelines%20for%20Community%20Noise%20-%20WHO.pdf .

14.Who (Int.). Guidelines for community noise: 4 guidelines values [internet]. 1999 [last accessed on 2019 jan. 13]. Available from: http://www.who.int/docstore/peh/noise/Commnoise4.htm.

15.American academy of pediatrics joint committee on infant hearing (US). Position statement: principles and guidelines for early hearing detection and intervention programs. Pediatrics. 2007 [last accessed on 2018 may 3]; 120(4):898-921. Available from: https://pediatrics.aappublications.org/content/120/4/898.

16.Kakehashi TY, Pinheiro EM, Pizzarro G, Guilherme A. Noise level in neonatal intensive unit. Acta Paul. Enferm [internet]. 2007 dez. [last accessed on 2018 may 21]; 20(4):404-409. Available from: http//www.scielo.br/pdf/ape/v20n4/02.pdf.

17.United States environmental protection agency (US). Information on levels of environmental noise requisite to protect public health and welfare with an adequate margin of safety [Report]. Washington: Government Printing Office [internet]. 1974 [last accessed on 2018 jul. 12]. Available from: http://www.epa.gov/storet/dbtop.html.

18.Macedo ISC, Mateus DC, Costa EMGC, Asprino ACL, Lourenço EA. Noise assessment in intensive care units. Braz. J. Otorhinolaryngol [internet]. 2009 dez. [last accessed on 2018 may 19]; 75(6):844-846. Available from: http//www.scielo.br/pdf/bjorl/v75n6a12.pdf.

19.ABNT (BR). NBR 10152: níveis de ruído para o conforto acústico. Rio de Janeiro: ABNT. 1987.

20.Galindo APG, Caicedo Y, Camargo VPAM. Noise level in intensive care units of a public university hospital in Santa Marta (Colombia). Medicina Intensiva [english edition]. 2016; 40(7):403-410.

21.Wachman EM, Lahav A. The effects of noise on preterm infants in the NICU. Arch Dis Child Fetal Neonatal. 2011; 4:305–9.

22.Morris BH, Philbin MK, Bose C. Physiological effects of sound on the newborn. J Perinatol 2000; 20:S55–60.

23.Darcy AE, Hancock LE, Ware EJ. A descriptive study of noise in the neonatalintensive care unit. Ambient levels and perceptions of contributing factors. AdvNeonatal Care 2008; 8:165–75.

24.Krueger C, Wall S, Parker L, Nealis R. Elevated sound levels within a busy NICU. Neonatal Netw [internet]. 2005 [last accessed on 2019 may 2]; 24(6):33-37. Available from: https://connect.springerpub.com/content/sgrnn/24/6/33.

25.Lasky RE, Williams AL. Noise and light exposures for extremely low birthweight newborns during their stay in the neonatal intensive care unit. Pediatrics2009;123:540–6.

26.Bremmer P, Byers JF, Kiehl E. Noise and the premature infant: physiological effects and practice implications. J. ObstetGynecol Neonatal Nurs [internet]. 2003 [last accessed on 2018 jun. 9]; 3(4):447-454. Available from: https://doi.org/10.1177/0884217503255009.

27.Brown G. NICU Noise and the Preterm Infant. Neonatal Network: The Journal of Neonatal Nursing 2009; 28(3):165–173. doi:10.1891/0730-0832.28.3.165.

28.Bridi AC, et al. Tempo estímulo-resposta da equipe de saúde aos alarmes de monitorização na terapia intensiva: implicações para a segurança do paciente grave. Rev. Bras. Ter. Intensiva [internet]. 2014 mar. [last accessed on 2019 oct. 6]; 26(1):28-35. Available from: http://dx.doi.org/10.5935/0103-507X.20140005.

29.Santos F, Silva RCL, Ferrão PPDA, Ribeiro AS, Passamani RF. Fadiga de alarmes de equipamentos eletromédicos em terapia intensiva. Rev. Enferm. UFPE [internet]. 2014 mar. [last accessed on 2019 aug. 7]; 8(3):687-694. Available from: https://periodicos.ufpe.br/revistas/revistaenfermagem/article/view/9726.

30.Siebig S, Kuhls S, Imhoff M, Langgartner J, Scholmerich J, Gather U, et al. Collection of annotated data in a critical validation study for alarm algorithms in intensive care-a methodologic framework. J. Crit. Care [internet]. 2010 [last accessed on 2019 oct. 6]; 25(1):128-135. Available from: https://doi.org/10.1016/j.jcrc.2008.09.001.

31.Kaur H, Rohlik GM, Nemergut ME, Tripathi S. Comparison of staff and family perceptions of causes of noise pollution in the Pediatric Intensive Care Unit and suggested intervention strategies. Noise Health. 2016; 18:78-84.

32.Goldstein J, Laliberte A, Keszler M. Ambient Noise Production by High-Frequency Neonatal Ventilators. The Journal of pediatrics. 2019; 204:157-161.

33.Uchoa NT, Procianoy RS, Lavinsky L, Sleifer P. Prevalência de perda auditiva em recém-nascidos de muito baixo peso. J. Pediatr. [internet]. 2003 [last accessed on 2018 nov. 15]; 79(2):123-128. Available from: http://dx.doi.org/10.1590/S0021-75572003000200006.

34.Grecco GM, Tsunemi MH, Balieiro MMFG, Kakehashi TY, Pinheiro EM. Repercussões do ruído na unidade de terapia intensiva neonatal. Acta Paul. Enferm [internet]. 2013 [last accessed on 2018 jun. 11]; 26(1):1-7. Available from: http://www.scielo.br/pdf/ape/v26n1/02.pdf.

35.Darbyshire JL, Muller-trapet M, Cheer J, Fazi FM, Young JD. Mapping sources of noise in an intensive care unit. Anaesthesia. 2019; 74(8):1018-1025.

36.Salú MS, Louro TQ, Tonini T, da Silva RCL, de Figueiredo NMA, da Silva CRL. Níveis de pressão sonora em uma unidade de terapia intensiva pediátrica. Rev. Enferm. UFPE [internet]. 2015 fev. [last accessed on 2018 aug. 16]; 9(2):918-926. Available from: https://pdfs.semanticscholar.org/c8ae/5edf555dd1fbf1dace55a726d266e98c12e4.pdf.

37.Smith SW, Ortmann AJ, Clark WW. Noise in the neonatal intensive care unit: a new approach to examining acoustic events. Noise Health. 2018 [last accessed on 2020 feb 17]; 20:121-130. Available from: http://www.noiseandhealth.org/text.asp?2018/20/95/121/239583.

38.Knutson A. Acceptable Noise Levels for Neonates in the Neonatal Intensive Care Unit. Independent Studies and Capstones. 2013[last accessed on 2020 feb 17]. Available from: http://digitalcommons.wustl.edu/pacs_capstones/643.

39.Chawla S, Barach P, Dwaihy M, Kamat D, Shankaran S, Panaitescu B, et al. A targeted noise reduction observational study for reducing noise in a neonatal intensive unit. Journal of Perinatology. 2017; 37:1060-1064.

40.Kol E, Aydın P, Dursun O. The effectiveness of environmental strategies on noise reduction in a pediatric intensive care unit: creation of single-patient. Journal for Specialists in Pediatric Nursing. 2015; 20:210-217. doi:10.1111/jspn.12116.

41.Cvach M. Monitor alarm fatigue: an integrative review. Biomed. Instrum. Technol. [internet]. 2012 [last accessed on 2019 oct. 3]; 46(4):268-277. Available from: https://doi.org/10.2345/0899-8205-46.4.268.

42.da Silva RCL, Fittipaldi A, Louro TQ, da Silva CRL. Alarmes em Unidades de Terapia Intensiva e suas implicações para o conforto do paciente. Rev enferm UFPE [internet]. nov. 2012 [last accessed on 2020 apr. 21]. Available from: http://www.revista.ufpe.br/revistaenfermagem/index.php/revista/article/download/3012/4733.

43.Graham KC, Cvach M. Monitor alarm fatigue: standardizing use of physiological monitors and decreasing nuisance alarms. Am. J. Crit. Care, [internet]. 2010 [last accessed on 2019 oct. 4]; 19(1):28-34. Available from: http://ajcc.aacnjournals.org/content/19/1/28.short.

44.Kawai Y, Weatherhead JR, Traube C, Owens TA, Shaw BE, Fraser EJ, et al. Quality improvement initiative to reduce pediatric intensive care unit noise pollution with the use of a pediatric delirium bundle. J Intensive Care Med. 2019; 34(5):383-390.

45.Williams A, van Drongelen W, Lasky RE. Noise in contemporary neonatal intensive care. J Acoust Soc Am. 2007; 121:2681-2690.

46.Pereira RP, Toledo RN, do Amaral JLG, Guilherme A. Qualificação e quantificação da exposição sonora ambiental em uma unidade de terapia intensiva geral. Rev Bras Otorrinolaringol [internet]. 2003 [last accessed on 2020 apr. 22]; 69(6):766-771. Available from: https://doi.org/10.1590/S0034-72992003000600007.

47.Graven SN. Sound and the developing infant in the NICU: conclusions and recommendations for care. J Perinatol. 2000; 20(8[2]):S88–S93.

48.Abdeyazdan Z, Ghassemi S, Marofi M. The effects of earmuff on physiologic and motor responses in premature infants admitted in neonatal intensive care unit. Iran J Nurs Midwifery Res. 2014; 19(2):107–112.

49.Al-Samsam RH, Cullen P. Sleep and adverse environmental factors in sedated mechanically ventilated pediatric intensive care patients. Pediatr Crit Care Med. 2005; 6(5):562-567.

50.Blomkvist, V. Acoustics and psychosocial environment in intensive coronary care. Occupational and Environmental Medicine. 2005; 62(3):e1-e1. Available from: doi:10.1136/oem.2004.017632.

51.Carvalho WB, Pedreira ML, de Aguiar MA. Noise level in a pediatric intensive care unit. J Pediatr.: Rio de janeiro. 2005; 81(6):495-498.

52.McAndrew NS, Leske J, Guttormson J, Kelber ST, Moore K, Dabrowski S. Quiet time for mechanically ventilated patients in the medical intensive care unit. Intensive Crit Care Nurs. 2016; 35:22-27.

53.Elbaz M, Leger D, Sauvet F, et al. Sound level intensity severely disrupts sleep in ventilated ICU patients throughout a 24-h period: a preliminary 24-h study of sleep stages and associated sound levels. Ann Intensive Care. 2017; 7(1):25.

54.Bailey E, Timmons S. Noise levels in PICU: An evaluative study. Pediatric Nursing. 2005; 17(10):22-26.

55.Cranmer K, Davenport L. Quiet time in a pediatric medical/surgical setting. Journal of PediatricNursing. 2013; 28:400–405.

56.Jousselme C, Vialet R, Jouve E, Lagier P, Martin C, Michel F. Efficacy and mode of action of anoise-sensor light alarm to decrease noise in thepediatric intensive care unit: A prospective randomizedstudy. Pediatric Critical Care Medicine. 2011; 12:e69–e72.

57.Shaffner DH. What does it take to get some peace and quiet in the pediatric intensive care unit? Pediatric Critical Care Medicine. 2011; 12(2):238-240.

58.Jordão KR, Pinto LA, Machado LR, Costa LB, Trajano ET. Possible stressors in a neonatal intensive care unit at a university hospital. Possíveis fatores estressantes na unidade de terapia intensiva neonatal em hospital universitário. Rev Bras Ter Intensiva. 2016; 28(3):310–314. doi:10.5935/0103-507X.20160041.

59.Nogueira MF, Di Piero KC, Ramos EG, Souza MN, Dutra MV. Mensuração de ruído sonoro em unidades neonatais e incubadoras com recém-nascidos: revisão sistemática de literatura. Rev Latino-Am Enfermagem. 2011; 19(1):2012–2021.

60.Manzini PJC. Nível de pressão sonora em unidade de terapia intensiva pediátrica de Brasília- DF. Monografia[residência médica]. 2015.

61.Viana RAPP, Vargas MAO, Carmagnani MIS, Tanaka LH, da Luz KR, Schmitt PH. Perfil do enfermeiro de terapia intensiva em diferentes regiões do Brasil. Texto contexto-enferm [internet]. 2014 mar. [last accessed on 2018 nov. 9]; 23(1). Available from: http://www.scielo.br/pdf/tce/v23n1/pt_0104-0707-tce-23-01-00151.pdf.

62.Richardson A, Allsop M, Coghill E, Turnock C. Earplugs and eye masks: do they improve critical care patients′ sleep? Nurs. Crit. Care. 2007; 12:278-86.

63.Johansson L, Bergbom I, Waye KP, Ryherd E, Lindahl B. The sound environment in an ICU patient room: a content analysis of sound levels and patient experiences. Intensive Critical Care Nursing, [internet]. 2012 [last accessed on 2018 sep. 22; (28):269-279. Available from: https://doi.org/10.1016/j.iccn.2012.03.004.

64.Weich TM, Ourique AC, Tochetto TM, de Franceschi CM. Eficácia de um programa para redução de ruído em unidade de terapia intensiva neonatal. Rev. bras. ter. intensiva. 2011 [last accessed on 2020 apr. 22]; 23(3). Available from :http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-507X2011000300011&lng=en&nrm=iso.