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Noise in an Intensive Care Nursery/Newborn Unit

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Abstract

Objective: The study aimed to analyze the existing noise levels in the Neonatal Intensive Care Unit (NICU) of a Hospital in Northern Portugal, to determine the main noise sources and to compare the values obtained with those recommended by international agencies.

Sample: 500 hours of measurement of the NICU's general sound environment and approximately 280 hours of the sound inside the incubators.

Methods: The measurements were performed with two sound level meters Brüel and Kjaer, 2260 Investigator model and 2236 model class 1, and dosimeters Bruel Kjaer, 4445 model and and CESVA DC 112, class 2.

Results: Sound levels were recorded in different places in NICU. It was found that the recorded sound levels were higher than those recommended by various international bodies (American Academy of Pediatrics; World Health Organization; US Environmental Protection Agency) in the various indicators. As the noise level that a newborn is subject may compromise their health and development, it was also proposed measures that aim to reduce noise level in these units.

Keywords: Noise; Neonatal intensive care unit; Assessment

Introduction

The necessary technical equipment for quality assistance to neonates, admitted to Neonatal Intensive Care Units, has become increasingly sophisticated and advanced do to the evolution of technology. However, this evolution is also accompanied by an increase of sound pressure levels.

In a NICU there are several sources of noise that may contribute to the existence of high sound levels on site: incubators' components (fans, suction equipment of secretions, oxygen support, alarms), ancillary support equipment, handling of incubators by the nursing team and medical team (opening and closing doors, for example), miscellaneous tasks of cleanup crews and the environment outside the living room unit (professionals and family conversation, material transport in strollers).

High levels of noise can have an impact on health in general, including at the level of hearing loss, increased blood pressure, heart rate and respiratory rate level changes. Anagnostakis et al. [1,2] and Bergman et al. [3] report in their studies the hearing loss of children born prematurely and who remained in Neonatal Intensive care units (NICU). Erenberg et al. [4] verified an increased incidence of bilateral hearing loss in children who have gone through a NICU comparing to children with birth considered normal. In addition to the auditory effects, the exposure of newborns to high levels of noise can cause disturbances in sleep patterns, irritability, restlessness, crying, fatigue, increase in oxygen consumption and heart rate, desaturation, apnoea and bradycardia [5-7]. Animal studies have also shown that prolonged exposure to high frequency sounds altered the formation of neural connections in the central auditory nervous system [8]. Other outlined secondary effects of excessive noise in premature newborns are changes in cardio-respiratory system of cerebral perfusion [6,7].

The longer the newborn stays in the unit, the greater the exposure to noise, which is a significant negative contributor for newborns at the time of their hospitalization in NICU. Newborns can spend weeks or even months in a NICU and are thus subjected to auditory sensory stimuli that may cause behavioral and physiological disorders [9,10].

The US Environmental Protection Agency [11] (EPA) recommended sound levels below 45 dBA during the day and 35 dBA at night to reduce the risk of noise exposure to hospital patients. The American Academy of Pediatrics [5] supports the recommendation from EPA, emphasizing that noise levels above 45 dBA may result in cochlear damage or disrupt the normal growth and development of premature infants. The World Health Organization [12] recommends that daytime noise levels in patient treatment rooms should not exceed 35 dBA (Table 1).

The acoustic parameters presented in Table 1 are the equivalent continuous A-weighted sound pressure level, L_{Aeq}, the highest noise level, L_{max} and the sound level that is exceeded in 10%, in the measurement time period, L_{10}. In Portugal, the Central Administration of the Health System, I.P. in «Recommendations and Technical Specifications of the Hospital Building» [13], concerning the acoustic comfort, only states that the building should be designed so as to provide users with good acoustic comfort, and must comply with the existing regulations', without however existing any specific guidelines for Neonatal Intensive care units.

Evaluation location–NICU

Noise assessment was held in the Neonatal Intensive Care Unit (NICU) of a central hospital in Northern Portugal. This Neonatal Intensive Care Unit has a room with support equipment for 9 incubators (Figure 1) the room is lined in length by a glass structure, directed to the exterior, and a concrete structure that separates the floor hall from

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the NICU. At one end of the unit there is a control room that allows supervising the equipment that monitors vital signs of newborns and, at the other end, a material preparation room. The Hall has a door with direct access to the incubator room, used by health professionals, and a second door also allowing access to the incubator room which is used by family members.

Nursing teams and staff operate in shifts of 8 hours with the following schedule: day shift (07 h-15 h); afternoon shift (15 h-23 h), night shift (23 h-07 h).

Measurement and Methodology

The measurements were performed with two sound level meters Brüel and Kjaer, 2260 Investigator model and 2236 model class 1, and dosimeters Bruel Kjaer, 4445 model and and CESVA DC 112, class 2. The appliances have been previously calibrated by an accredited laboratory.

Acoustic parameters such as L_{Aeq}, L_{max}, L_{10}, in dBA, as well as the C-weighted peak sound pressure level, L_{Cpico}, were recorded in dBC. The measurements were made with a Fast response time and with integration of 1 second, in order to identify and characterize specific events of noise.

For the characterization of the general sound environment of the NICU, measurements were conducted at different points of the unit using the sound level meters; the equipment was placed at a height of about 1.5 m from the floor (Figure 2). Noise dosimeters were used to measure the sound level inside the incubators, the microphone was located as close as possible to the newborn's hearing system (Figure 3). During the process of noise measurement there was always care not to interfere with the positioning and well-being of newborns, with the tasks of the medical staff and with the NICU support equipment.

In order to analyze the newborns response to noise exposure, the vital signs of the newborns: heart rate, respiratory rate and oxygen saturation level were recorded.

To evaluate the influence of the incubator to the sound levels registered, noise measurements were conducted in an empty incubator in different working conditions of oxygen support with different flow rates (0; 2.2; 4.4 and 5.5 l/min). For these measurements all sources of external noise were eliminated.

Measurements were performed throughout the day, during the daytime and nighttime, in various non-consecutive days. More than 500 hours of measurement for characterization of general sound environment of NICU, and approximately 280 hours for characterization of the sound inside the incubators were obtained.

In order to compare the obtained sound levels with agencies' recommended values each day was divided in two periods: from 7 h to 23 h, considering the daytime (morning and afternoon) and the nighttime, from 23 h to 7 h.

In order to study the relationship between the sound level and the number of incubators being used, measurements were carried out in different conditions of occupation of the NICU, from 2 to 6 newborns.

Noise level parameters were calculated using the sound level meters and dosimeters' software. These data were statistically analysed using the IBM SPSS Statistics 25.

Entity	Indicator. dBA				
	L_{Aeq}	L_{Aeq} daytime	L_{Aeq} nighttime	L_{max}	L_{10}
American Academy of Pediatrics (AAP)	45	-	-	65	50
Environmental Protection Agency (EPA)	-	45	35	-	-
World Health Organization (WHO)	30 (max. 40)	-	-	-	-
Sound Study Group (SSG) of National Resource Center (American)	<50 ($L_{Aeq,1h}$)	-	-	70	55

Table 1: Recommended values by different entities for the NICU.

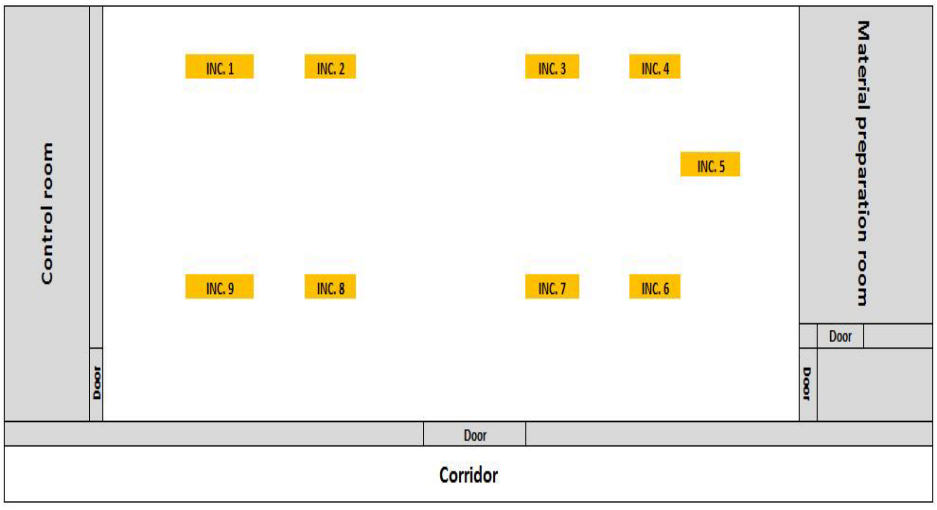

Figure 1: NICU and incubators layouts.

Figure 2: Example of the sound level meter localization in the NICU.

Figure 3: Example of placement of dosimeter in the incubator.

Results

Sound levels

Table 2 presents the measured acoustic parameters in the NICU, outside the incubator, for the day time and night time periods respectively. The acoustic parameters presented are L_{Aeq}, and L_{10} (mean ± standard deviation) L_{max} and L_{Cpico}.

As can be seen, through the analysis of Table 2, all noise parameters (L_{Aeq}, L_{max}, L_{10}) are higher than the recommended values proposed by several agencies (AAP and EPA).

The parametric t-test one sample revealed, for daytime period, significant higher values of L_{Aeq} than the ones recommended by AAP and EPA (p-value <0,001). This test also revealed significant higher values of L_{Aeq} than the ones recommended by EPA, for night time period, (p-value <0,001).

The paired sample t-test results showed that mean L_{Aeq} value obtained for daytime period were significantly higher than the mean value obtained for the nighttime period in 2,1 dBA (p-value <0,001).

Table 3 presents the different values of L_{Aeq} (mean ± standard deviation) obtained based on the number of incubators occupied (number of newborns) for the different periods (day time and night time).

One-way ANOVA analysis showed the existence of statistically significant differences in the mean values obtained for L_{Aeq} considering the different occupation of the incubators (from 2 to 6 newborns) (p-value=0.002).

Period	$L_{Aeq,T}$ dBA	L_{10} dBA	L_{max} dBA	L_{Cpico} dBC
Day time	56.2 ± 4.1	59.2 ± 3.5	96.4	109.4
Night ime	53.6 ± 4.1	58.0 ± 3.5	92.0	113.0

Table 2: LAeq. L10. Lmax and LCpico during day time and night time.

Number of Incubators Occupied	2	3	4	5	6
L_{Aeq} daytime, dBA	52.9 ± 1.9	58.0 ± 5.4	56.6 ± 1.9	60.2 ± 0.5	60.5 ± 0.1
L_{Aeq} nighttime, dBA	50.7 ± 2.0	52.3 ± 1.3	58.6 ± 1.4	57.2 ± 2.1	60.1 ± 0.2

Table 3: L_{Aeq}. on basis of incubators occupied (number of new borns) for day time and night time.

Sound levels-operation of incubators

The oxygen support equipment contributes significantly to the increase in the sound level inside the incubator as can be seen in Table 4. Under these conditions, for the same incubator, the noise level increase was 13.5 dBA for an oxygen flow rate of 2.2 l/min and 18.9 dBA for a flow rate of 5.5 l/min.

Sound levels-noise sources

Table 5 presents the noise level recorded in the NICU, and in incubators (INC) caused by other events in the surroundings of the unit, such as support equipment's alarms and parents, medical, nursing and staff teams conversation. The values correspond to the mean ± standard deviation value of L_{Aeq}.

The independent sample t-test results showed that the values of L_{Aeq} registered in the NICU were significant higher than the ones registered inside the incubator (INC) (p-value <0.05).

The events which led to higher values of L_{Aeq}, inside the incubator, were the secretions' suction process (73.4 ± 1.6 dBA) and the opening of the probe bag (69.0 ± 3.5 dBA).

An attempt was made to study the influence of noisy events outside the incubator in the heart rate of a neonate; however, due to instability of the newborns, there is a great variability of these vital signs. Also, the noise level caused by the accessories/equipment of the incubator is too high for the outside noise to be perceptible. These two factors made the task of studying the influence of an outside noise very difficult, for example, in the study of the heart rate of a neonate. In some cases it was possible to observe an increase in heart rate of the newborn after a high outside noise (Figure 4). However, this is not always the case: it wasn't possible to prove with statistical significance that there is a change in heart rate after a peak of noise coming from the outside.

Discussion of Results

Exposure to noise has been documented to have negative effects on the preterm infants, placing the neonates at risk of auditory processing disorders and future learning disabilities [14].

Sound levels recorded in the NICU are substantially higher than the recommended levels by the American Academy of Pediatrics [5], the US Environmental Protection Agency [11] and by the World Health Organization [12] as can be seen in the obtained values.

These values are in accordance with Santos et al. [15] that registered levels of 48.7 a 71.7 dBA in 3 Portuguese NICUs; Neille et al. [16] also identified noise levels greater than 45 dBA in 3 NICUs in Johannesburg, South Africa; Parra et al. [17] measured sound levels in 17 single or double rooms in a French NICU and obtained values of 60.6, 62.1 and 89.1 dBA for the mean L_{Aeq}, L_{10} and L_{max} respectively.

It was found that there is a remarkable correlation between the increase of existing sound levels in the NICU and the increase in the number of occupied incubators. The obtained values are influenced by other noise sources, being the various alarms the major contributor.

Working Condition	L_{Aeq} dBA
Condition 1-on: only with control equipment of T and RH	46.3 ± 0.9
Condition 2-on: control of T and RH+oxygen with low-flow rate-2.2 l/min	59.9 ± 0.4
Condition 3-on: control of T and RH+oxygen with medium volume-4.4 l/min	62.8 ± 0.3
Condition 4-on: control of T and RH+oxygen with higher volume-5.5 l/min	65.3 ± 1.1

Table 4: Sound levels inside the incubator with different equipment turned on for life support.

Event	Location	L_{Aeq} dBA
Oxygen support alarm	INC	66.1 ± 2.0
	NICU	71.2 ± 2.5
Vital signs monitor alarm	INC	56.7 ± 2.4
	NICU	63.0 ± 2.1
Pump and perfusion syringe	INC	59.0 ± 1.8
	NICU	68.4 ± 3.9
Incubator's alarm (T and RH)	INC	63.5 ± 0.8
	NICU	69.6 ± 3.3
Hall door beating	INC	54.9 ± 5.3
	NICU	56.9 ± 3.5
Conversation of medical staff and parents	INC	52.5 ± 3.4
	NICU	56.9 ± 4.7
Noise: staff tasks	INC	53.1 ± 3.2
	NICU	59.2 ± 5.5

Table 5: Sound levels in the NICU and within an incubator (INC) due to different events.

The noise produced by equipment should also be considered since the basic operation of incubator, in temperature and humidity control mode, reached average values of 46.3 dBA, being superior at all levels to the recommended by international entities. In situations where the newborns require the aid of oxygen support equipment, the average levels recorded inside the incubators were superior to 59.9 dBA, being much higher than the recommended values. Inside the incubator, the secretion suction system and the opening of the probe bag are the two events that cause the higher noise level.

It was also found that the noise produced by nursing and medical teams, the professionals and family members' conversation, the

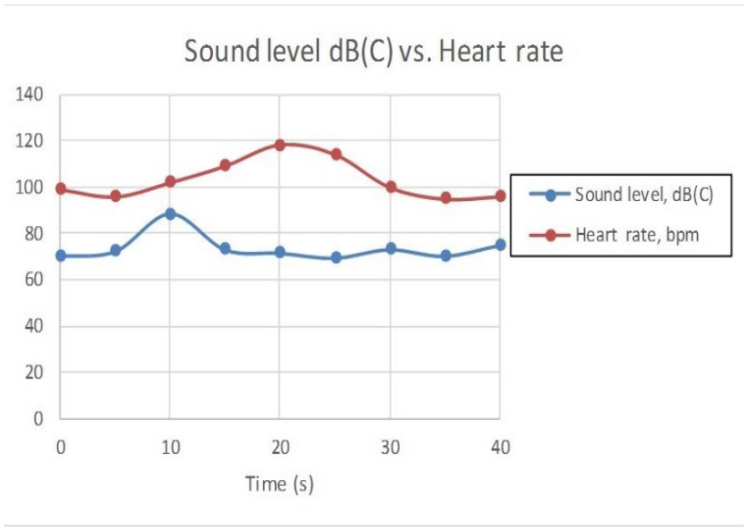

Figure 4: Sound level in the incubator and heart rate of the neonate.

transport of material in handling carts, the handling of equipment, significantly contributes to the high sound level presented.

In which regards to the L_{10}, neither of daytime and nighttime periods presented values lower than 50 dBA. Regarding the L_{max} the situation is also critical, not being verified in any day, on the daytime shifts or in the nighttime, L_{max} lower than 70 dBA.

Conclusion

The results showed that sound levels inside NICU are significantly higher than the limit values proposed by several organizations and are influenced by several sources such as supporting equipment operation, nursing and medical team's conversations, parent's visits, and adjacent infrastructures (hall, corridor). As consequence newborns are prone to develop specific diseases or several delays in their intellectual or physical development.

In view of these results, it is recommended to train the medical, nursing and auxiliary staff of the unit on the harm of the noise, as well as placement of signage (posters) promoting the minimum possible noise and silence for the newborn parents. As proposed by Swathi et al. [18] strategies should be developed to "sustain a culture of silence in NICU during nonemergency situations in order to reduce noise levels in the NICU. However, some authors consider that such measures have a limited or temporary success [19,20].

One measure to protect premature infants against noise in the NICU could be achieved by the use of earmuffs [21-24]. D´Agati et al. [21], Duran et al. [22] and Zahra et al. [23] concluded that when infants wore the earmuffs they improve significantly their physiological and motor state. However, Philbin [24] emphasizes the importance of the lack of information about the effect of these protectors on posture, in the later format of head and the newborns' skin integrity itself.

In addition, constructive measures such as implementation of sound insulation of walls and ceilings (surfaces with less reverb) and reducing the noise of opening and closing doors with spongy, absorbable impact material should be put to practice. It is also suggested that architects and engineers follow the Standard Recommendations for a NICU [25] before design, construct and use of a new NICU.

The reduction of noise in the general environment also brings benefits to the health of parents and caregivers, by decreasing stress and reducing their levels of burnout and depression, which are already psychologically weaker due to the situation of the newborns. The health of professionals benefits as well since the effects of noise exposure decrease.

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