



## ORIGINAL

# Noise level in intensive care units of a public university hospital in Santa Marta (Colombia)<sup>☆</sup>



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### KEYWORDS

Public health;  
Intensive therapy;  
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### Abstract

**Objective:** To evaluate the noise level in adult, pediatric and neonatal intensive care units of a university hospital in the city of Santa Marta (Colombia).

**Design:** A descriptive, observational, non-interventional study with follow-up over time was carried out.

**Materials and methods:** Continuous sampling was conducted for 20 days for each unit using a type 1 sound level meter, filter frequency in A weighting and Fast mode. We recorded the maximum values, the 90th percentile as background noise, and the continuous noise level.

**Results:** The mean hourly levels in the adult unit varied between  $57.40 \pm 1.14$  and  $63.47 \pm 2.13$  dBA, with a maximum between  $71.55 \pm 2.32$  and  $77.22 \pm 1.94$  dBA, and a background noise between  $53.51 \pm 1.16$  and  $60.26 \pm 2.10$  dBA; in the pediatric unit the mean hourly levels varied between  $57.07 \pm 3.07$  and  $65.72 \pm 2.46$  dBA, with a maximum of  $68.69 \pm 3.57$ – $79.06 \pm 2.34$  dBA, and a background noise between  $53.33 \pm 3.54$  and  $61.96 \pm 2.85$  dBA; the neonatal unit in turn presented mean hourly values between  $59.54 \pm 2.41$ – $65.33 \pm 1.77$  dBA, with a maximum value between  $67.20 \pm 2.13$  and  $77.65 \pm 3.74$  dBA, and a background noise between  $55.02 \pm 2.03$  and  $58.70 \pm 1.95$  dBA. Analysis of variance revealed a significant difference between the hourly values and between the different units, with the time of day exhibiting a greater influence.

**Conclusions:** The type of unit affects the noise levels in intensive care units, the pediatric unit showing the highest values and the adult unit the lowest values. However, the parameter exerting the greatest influence upon noise level is the time of day, with higher levels in the morning and evening, and lower levels at night and in the early morning.

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**PALABRAS CLAVE**

Salud pública;  
Terapia intensiva;  
Medición del ruido;  
Salud ambiental

## Nivel de ruido en unidades de cuidado intensivo de un hospital público universitario en Santa Marta (Colombia)

**Resumen**

**Objetivo:** Evaluar el nivel de ruido en las unidades de cuidado intensivo adulto, pediátrico y neonatal de un hospital universitario de la ciudad de Santa Marta (Colombia).

**Diseño:** Estudio descriptivo, observacional no intervencionista y con seguimiento a lo largo del tiempo.

**Materiales y métodos:** Se realizó un muestreo continuo durante 20 días por cada unidad utilizando un sonómetro tipo 1, con filtro de ponderación frecuencial A y temporal Fast. Se registraron los valores máximos, el percentil 90 como ruido de fondo y el nivel continuo de ruido.

**Resultados:** Los niveles medios horarios variaron entre  $57,40 \pm 1,14$ - $63,47 \pm 2,13$  dBA para la unidad de adultos, con un máximo entre  $71,55 \pm 2,32$ - $77,22 \pm 1,94$  dBA y un ruido de fondo entre  $53,51 \pm 1,16$ - $60,26 \pm 2,10$  dBA; para la unidad pediátrica la media horaria se establece entre  $57,07 \pm 3,07$ - $65,72 \pm 2,46$  dBA, con un máximo de  $68,69 \pm 3,57$ - $79,06 \pm 2,34$  dBA, y de  $53,33 \pm 3,54$ - $61,96 \pm 2,85$  dBA de ruido de fondo; finalmente, la unidad neonatal reporta entre  $59,54 \pm 2,41$ - $65,33 \pm 1,77$  dBA la media horaria, los máximos entre  $67,20 \pm 2,13$ - $77,65 \pm 3,74$  dBA, y fondo de  $55,02 \pm 2,03$ - $58,70 \pm 1,95$  dBA. El ANOVA evidenció una diferencia significativa entre los valores horarios y entre las unidades de cuidado intensivo, mostrando una mayor influencia la hora del día.

**Conclusiones:** Los niveles de ruido en las unidades de cuidado intensivo se ven afectados por el tipo de unidad; se presentaron los valores más altos en la unidad pediátrica y los más bajos en la de adultos. No obstante, el parámetro que más influye en el nivel es la hora del día, con mayores niveles en la mañana y la tarde, y menores en la noche y la madrugada.

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**Introduction**

In hospitals, intensive care units (ICUs) are regarded as areas exposed to noise produced by medical equipment and human activity. Excessive noise levels can lead to stress and delirium among the patients admitted to such Units,<sup>1-4</sup> as well as to fatigue and stress among the healthcare personnel.<sup>5-7</sup>

The literature shows that approximately 50% of all patients develop important sleep disturbances during their stay in the ICU. In this regard, noise reduces the duration and number of rapid eye movement (REM) periods,<sup>8</sup> with an impact upon the physiological and psychological wellbeing of critical patients in the form of metabolic, endocrine and immune alterations.<sup>3</sup>

In the case of newborn infants admitted to such Units, it has been estimated that continuous and persistent exposure to excessive noise can lead to hearing loss, increased intracranial pressure, stress, arterial hypertension, metabolic instability, sleep disturbances, irritability and loss of appetite, particularly among premature infants.<sup>9-11</sup>

The literature reports mean a noise level in ICUs of 68 decibels A (dBA). As illustrative examples, an Austrian hospital recorded an average of 60-65 dBA, while a University Hospital in Valencia (Spain) recorded a level of 55 dBA. In a Children's Hospital in Cincinnati (USA) the mean noise level was found to be 71.9 dBA, while in the ICU of the Hospital of Manitoba (Canada) the level was 68 dBA.<sup>12,13</sup> In adult ICUs (AICUs), the reported mean equivalent noise level ( $LA_{eq}$ ) was

52-84 dBA,<sup>14-16</sup> while in pediatric ICUs (PICUs), the literature describes levels in the range of 48-72 dBA.<sup>17-20</sup> Lastly, the noise levels in neonatal ICUs (NICUs) are reported to range between 45 and 90 dBA.<sup>11,21-24</sup>

The present study was carried out to assess the equivalent continuous noise levels in three ICUs of a hospital in the city of Santa Marta (Colombia), and to evaluate the existence of differences or similarities among the analyzed Units -taking into account the repercussions of excessive noise upon critical patients admitted to the ICU.

**Material and methods****Study setting**

The study was carried out in a university hospital in the city of Santa Marta (Colombia), with three general ICUs (no differentiation being made according to disease type) classified as AICU, PICU and NICU. The AICU cares for adults and young individuals over 15 years of age and has 19 beds with a mean occupation of  $10 \pm 2$  patients and an attending personnel of  $7 \pm 3$  professionals. The PICU in turn cares for patients between 31 days and 14 years of age and has 7 beds with a mean occupation of  $3 \pm 2$  patients and an attending personnel of  $5 \pm 1$  professionals. Lastly, the NICU cares for newborn infants between 0 and 31 days of age and has 14 cribs with a mean occupation of  $8 \pm 1$  patients and an attending personnel of  $4 \pm 0$  professionals.<sup>25</sup>

The ICUs operate in three shifts: morning (7:00–13:00 h), afternoon (13:00–19:00 h) and night (19:00–7:00 h<sup>+</sup>). Two family visiting periods of 20 min each have been established: at 11:00 h and 17:00 h. In the NICU and PICU there are 8 feeding times per day at intervals of 3 h, starting at 00:00 h, while the AICU has three feeding times: at 8:00 h, 12:00 h and 18:00 h.

Each ICU is staffed by a specialized physician who conducts a round of the Unit three times a day. In the AICU the rounds take place at 9:00 h, 14:00 h and 20:00 h, while in the PICU and NICU they take place at 7:15 h, 14:00 h and 20:00 h. In addition, the general practitioners in each ICU conduct their rounds at the patient bedside at the times of change in shift.

The procedures carried out in each ICU vary according to the requirements of the general practitioner and/or specialist, with no specific scheduling of such procedures. In effect, the latter are carried out in the course of each shift as requested by the medical personnel. The most common procedures are the collection of samples for laboratory tests, electrocardiograms, X-rays, the placement of central venous catheters, and interconsultation with the Ear, Nose and Throat, Nephrology and Urology Departments, among others, depending on the patient diagnosis.

## Sampling design

The present study comprises an analytical, observational and non-interventional design with follow-up over time. It is therefore defined as an analytical study with non-longitudinal follow-up (follow-up study).

Continuous sampling was carried out in each ICU during 20 days, based on the methodology described by Vélez-Pereira<sup>2</sup>. In the case of the AICU, the measurement campaign took place between 19 August and 8 September 2012; in the PICU it took place between 15 September and 5 October 2012; and in the NICU it took place between 23 March and 12 April 2013. The noise levels were recorded using a Casella type I sound level meter (model CEL-633-C1K1) programmed to record data every 60 s using filter frequency in A-weighting and Fast mode. The recorded acoustic parameters included  $LA_{eq,1h}$  (to establish the noise level in 1 h), percentile 90 ( $LA_{90}$ , to establish the background noise level), and  $LA_{max}$  (to establish the maximum values).

The sound level meter was positioned in each ICU considering the descriptions of Vélez-Pereira,<sup>2</sup> the conditions and internal dynamics of the ICU, and the authorizations and recommendations of the medical coordinators with the purpose of affecting the activities in the ICUs as little as possible. In the AICU we established a distance of 55 cm from the ceiling and 123 cm from the wall; in the PICU the distance was 55 cm from the ceiling and 540 cm from the wall; and in the NICU the distance was 60 cm from the ceiling and 215 cm from the wall.

## Data processing and statistical analyses

### Equivalent continuous level

Microsoft Excel<sup>®</sup> was used for noise data integration under 1-h intervals corresponding to the acoustic parameters investigated in each ICU ( $LA_{eq}$ ,  $LA_{max}$  and  $LA_{90}$ ). This allowed

us to analyze the variability associated to hourly or daily cycles in the course of the sampling time. The integrated mean was obtained by applying Eq. (1):<sup>2</sup>

$$LA_{eq,1h} = 10 \times \log_{10} \left[ \frac{\sum_{i=1}^n 10^{(Leq_{ij}/10)}}{n_j} \right] \quad (1)$$

where  $i$  corresponds to observation of the A-weighted equivalent continuous level reported in the hourly interval  $j$ , and  $n$  is the total number of observations  $i$  in the hour  $j$ .

## Statistical analysis

The statistical analysis was carried out with the IBM SPSS<sup>®</sup> version 20 statistical package, using the hourly averages of each ICU. Analysis of variance (ANOVA)<sup>2,23,26,27</sup> was used to identify statistically significant differences in the hourly averages. In addition, nested ANOVA was used to compare the three ICUs, with a view to identifying statistically significant differences between the results obtained in the three units and determining which factor exerts the strongest impact upon variance (hour and ICU). Lastly, and in order to establish the possible incidence of the Hawthorne effect among the healthcare personnel, an ANOVA was performed of the first 5 days of sampling versus the remaining 15 days.

## Results

On comparing the integrated mean hourly values of the three ICUs (Fig. 1), the highest  $LA_{eq,1h}$  values were seen to correspond to the PICU, with a noise level variation range of  $57.07 \pm 3.07$ – $65.72 \pm 2.46$  dBA, followed by the NICU, with levels of  $59.54 \pm 2.41$ – $65.33 \pm 1.77$  dBA, and the AICU, with levels of  $57.40 \pm 1.14$ – $63.47 \pm 2.13$  dBA. This information was confirmed by performing an ANOVA of the data, where a significant difference between ICUs was identified, influenced mainly by the time variation in the course of the day, with an  $F$ -ratio = 116.02 and  $p = 0.00$  (critical  $p$ -value = 0.05), and 95% significance level.

In contrast to the above, the three ICUs were found to exhibit similar trends with stable hourly levels between 07:30 h and 17:30 h, approximately; this was followed by a strong increase at 18:30 h, and from 19:00 h onwards a decrease was noted in  $LA_{eq,1h}$ , extending until approximately 04:30 h (Table 1). This was corroborated by the ANOVA of the hourly noise averages, with  $F = 26.07$  and  $p = 0.000$  (critical  $p$ -value = 0.05), yielding a significant difference between the hourly averages, with a 95% confidence level. This information was evidenced by the generation of homogeneous groups as established from the cluster analysis applied to the hourly data of the ICU (Fig. 2). The analysis showed the values to be low in the early morning hours in the ICU (1:00–4:00 h), with intermediate behavior in the late hours of the day (20:00–0:00 h and 5:00 h, nocturnal), and finally with the highest and most fluctuating noise values during the daytime (6:00–19:00 h, including morning and afternoon).

On examining the maximum noise values in the ICUs, we found the pattern to be the same as in the case of  $LA_{eq,1h}$ —the PICU yielding the highest levels ( $68.69 \pm 3.57$ – $79.06 \pm 2.34$  dBA), followed by the NICU ( $67.20 \pm 2.13$ – $77.65 \pm 3.74$  dBA) and finally the AICU ( $71.55 \pm 2.32$ – $77.22 \pm 1.94$  dBA). However, the values

**Table 1** Noise level integrated according to time of day and shifts.

Shift	Time	AICU		PICU		NICU	
		LA <sub>eq,1h</sub> (dBA)		LA <sub>eq,1h</sub> (dBA)		LA <sub>eq,1h</sub> (dBA)	
Morning	7:30	62.56	62.07	63.87	66.78	65.3	64.84
	8:30	60.84		64.97		65.1	
	9:30	61.18		65.72		64.0	
	10:30	61.35		63.98		64.3	
	11:30	61.06		64.36		62.7	
	12:30	63.47		64.62		63.4	
Afternoon	13:30	62.18	62.11	64.17	67.07	64.8	64.97
	14:30	61.59		63.92		63.7	
	15:30	60.83		65.59		63.8	
	16:30	61.18		64.90		63.5	
	17:30	61.63		64.04		63.8	
	18:30	63.43		64.88		64.9	
Night	19:30	61.93	59.95	65.19	64.35	63.0	62.94
	20:30	58.91		63.47		63.7	
	21:30	58.88		62.86		63.0	
	22:30	59.01		63.05		62.1	
	23:30	58.18		61.66		62.9	
	0:30	58.51		59.50		62.2	
	1:30	57.40		57.07		60.8	
	2:30	57.58		58.14		59.5	
	3:30	57.63		57.37		59.7	
	4:30	58.82		57.21		59.9	
	5:30	59.48		60.26		63.6	
	6:30	62.56		63.76		64.2	

LA<sub>eq,1h</sub> (dBA): 1 h equivalent noise level in decibels A; AICU: adult intensive care unit; NICU: neonatal intensive care unit; PICU: pediatric intensive care unit.

showed less variation than the integrated hourly noise data, with the exception of the NICU, which exhibited a greater range of variability than the other two ICUs, particularly in the early hours of the day. Regarding the ANOVA applied to the maximum noise levels, the type of ICU and time of day were seen to influence variance of the levels, with statistically significant differences (95% confidence level). However, the *F*-ratio of the hourly period (32.18) was greater than the *F*-ratio as per Unit (10.89)—thus indicating greater influence of the time of day upon the maximum noise levels in the ICU.

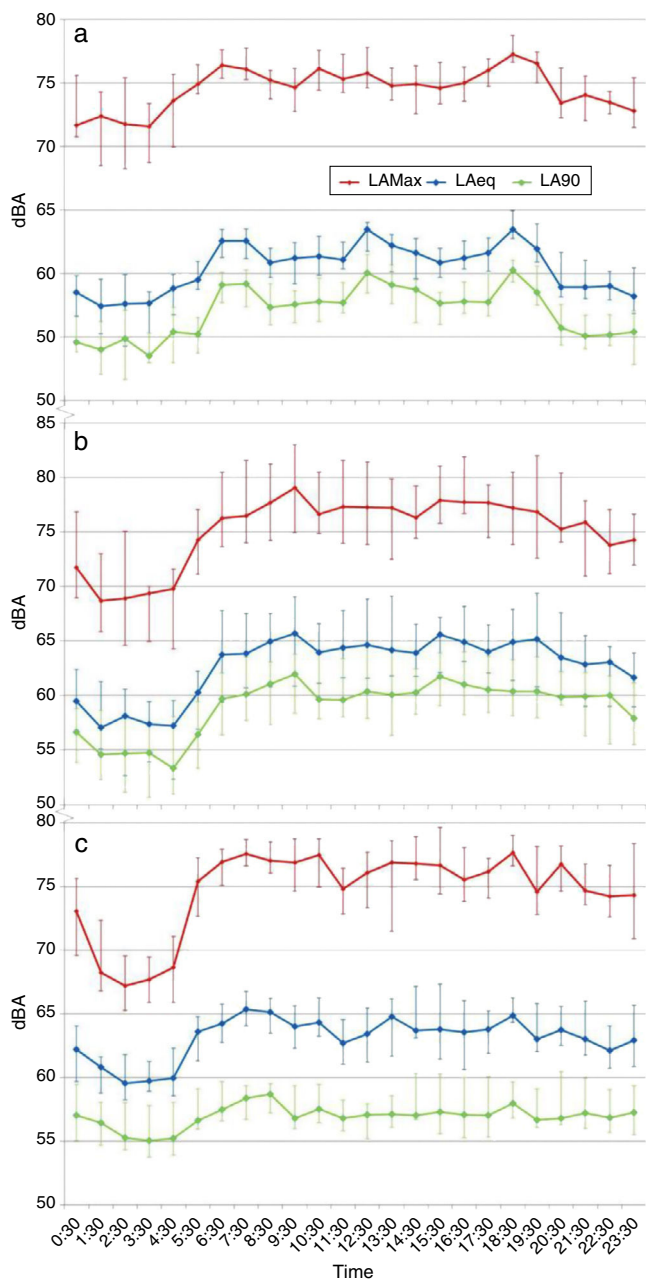
On the other hand, in relation to the results of the background noise, the order was found to differ with respect to the previous two acoustic parameters, being headed by the PICU (53.33 ± 3.54–61.96 ± 2.85 dBA), followed by the AICU in this case (53.51 ± 1.16–60.26 ± 2.10 dBA), and finally the NICU (55.02 ± 2.03–58.70 ± 1.95 dBA). However, as can be seen in Fig. 1, there was greater similarity in the variation of LA<sub>eq,1h</sub> and LA<sub>90</sub>, these values being closely comparable among the three ICUs. This situation was not observed in the case of the noise level (LA<sub>eq,1h</sub>) and maximum level (LA<sub>max</sub>). On applying the ANOVA to the background noise data, we again observed the influence of the Unit and time of day upon variation, with a greater influence than in the case of LA<sub>max</sub>, though lower for LA<sub>eq,1h</sub>—with an *F*-ratio of 76.04 for the parameter ICU, and of 20.22 in the case of the parameter time. In both cases a significant difference was recorded, with a 95% confidence level.

All this information was corroborated by the ANOVA applied to the parameters, reflecting the interaction of the type of ICU and the time of day with the recorded noise levels. In this regard, the *F*-ratio for the interaction of the parameters was 1.09 for LA<sub>eq,1h</sub>, followed by 2.19 for LA<sub>max</sub> and 3.33 for LA<sub>90</sub>. However, only in the case of the LA<sub>max</sub> values did the type of Unit fail to influence the variations, while in the case of LA<sub>eq,1h</sub> and LA<sub>90</sub> the influence in variation of the noise levels was 9.22% and 13.49%, respectively. In the case of the time of day, LA<sub>max</sub> was found to influence variance by 36.16%, versus 27.02% in the case of LA<sub>eq,1h</sub>, and 26.10% in the case of LA<sub>90</sub>.

Lastly, the analysis carried out to determine the presence of the Hawthorne effect showed that only in the case of the PICU could minor modifications be inferred in the behavior of the healthcare personnel or changes in the medical teams in the first days of sampling, since ANOVA only identified significant differences between the LA<sub>max</sub> and LA<sub>90</sub> values between the first 5 days versus the remaining 15 days (with a 95% level of significance).

## Discussion

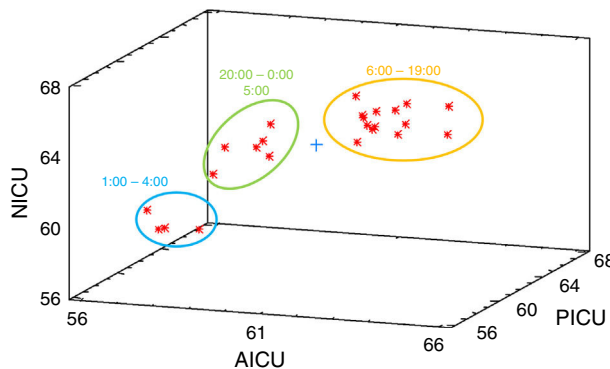
The analysis of the results obtained reflects the existence of important noise levels in all three ICUs. This is consistent with the data found in the literature, where noise increments have been recorded in ICUs, increasing from 57 dBA



**Figure 1** Hourly averages of the acoustic parameters. (a) Adult intensive care unit. (b) Pediatric intensive care unit. (c) Neonatal intensive care unit of the hospital. dBA: decibels A; LA<sub>eq</sub>: equivalent noise level; LA<sub>max</sub>: maximum noise level; LA<sub>90</sub>: noise level below which 90% of the measurements are found.

in the daytime and 42 dBA during the nighttime hours in the year 1960 to 72 dBA in the daytime and 60 dBA during the nighttime hours in the year 2005. This trend is mainly related to the increase in number of medical devices with acoustic alarms that serve as support for the medical activities in the ICU. An additional contributing factor is the noise generated essentially by human factors, including conversations among the personnel members, visits by the families, the falling of objects, opening and closing of doors, etc.<sup>9,12,28,29</sup>

On considering the LA<sub>eq</sub> values obtained and the noise levels contemplated by Resolution 8321 of 1983 of the

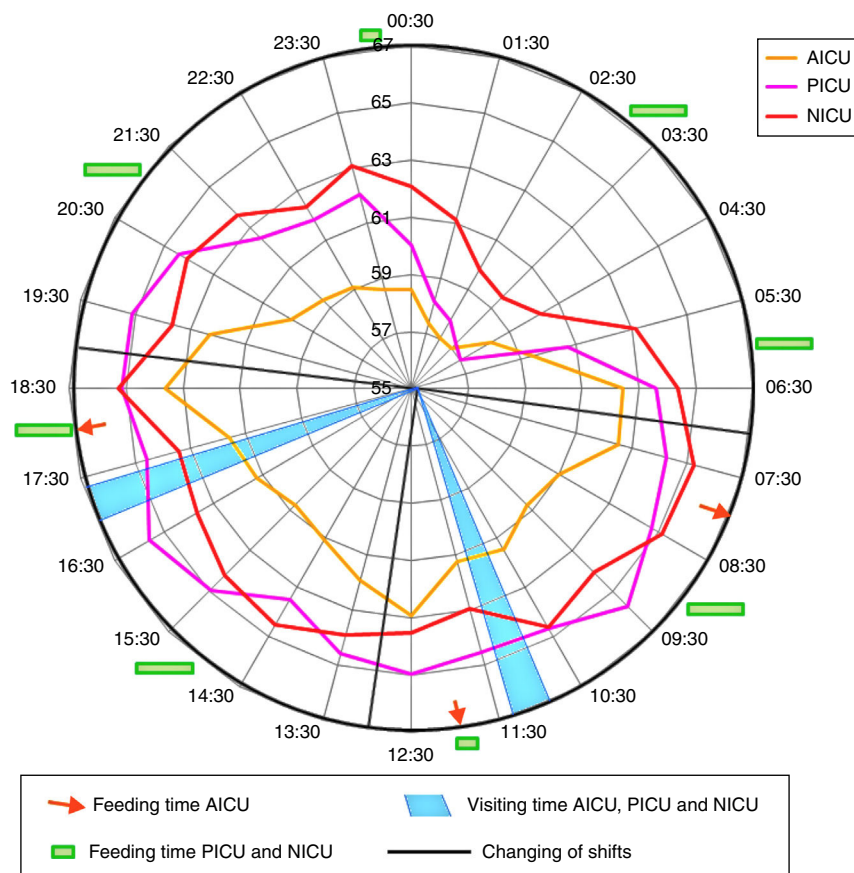


**Figure 2** Cluster plot or homogeneous groups of noise levels in the intensive care units based on the nearest neighbor approach (Euclidian metric distance). AICU: adult intensive care unit; NICU: neonatal intensive care unit; PICU: pediatric intensive care unit.

Colombian Ministry of Health,<sup>30</sup> it is clear that none of the three ICUs yielded mean levels of under 45 dBA (the limiting level for calm zones) during the sampling period. This situation is also observed in the literature, where the noise limits are frequently seen to be exceeded in ICUs.<sup>12,31</sup> These data are all the more serious considering that the background noise in the ICUs exceeded the maximum levels accepted by Colombian regulations and other international references—including the guidelines of the EPA (45 dBA in the daytime and 35 dBA at night), the National Institute of Occupational Health and Safety (40 dBA in the daytime and 35 dBA at night), Royal Decree 1386 of 1989 (40 dBA in the daytime and 35 dBA at night), the World Health Organization, the American Academy of Pediatrics (35 dBA in the daytime and 30 dBA at night), and the Chinese Medical Association (45 dBA in the morning hours, 40 dBA in the afternoon, and 20 dBA at night), among others.<sup>29,32-35</sup>

Our results show that the highest values of the different acoustic parameters are mainly recorded during the daytime, in the course of medical controls, visits by social workers, nutritionists and epidemiologists, and in the hours close to the changing of shifts in the case of the AICU and PICU. In the case of the NICU, we not only recorded this increase during the mentioned activities and at the changing of shifts, but also observed a slight increase in noise levels every 3 h, coinciding with feeding of the newborn infants (Fig. 3). This is consistent with the observations of González,<sup>36</sup> Lawson et al.,<sup>27</sup> Knutson<sup>37</sup> and Konkani and Oakley,<sup>28</sup> where the periods of greater noise in the ICU were correlated to the changing of shifts, the collection of laboratory test samples, visiting and feeding times, and the presence of social workers, nutritionists and physiotherapists.

The literature shows that noise has an impact upon patient recovery. A number of studies point to noise as one of the stressors underlying lack of sleep and physiological and psychological effects that prolong patient stay in the Unit.<sup>3,38</sup> Although the LA<sub>eq,1h</sub> values recorded in our three ICUs did not exceed 90 dBA (levels above which hearing damage can occur), they were above 65 dBA, which is associated to effects upon the hypothalamic-adrenal gland system, with alterations in heart rate and an increased risk



**Figure 3** Hourly averages of the noise levels contrasted with the times of day and routine activities in the intensive care unit. AICU: adult intensive care unit; NICU: neonatal intensive care unit; PICU: pediatric intensive care unit.

of complications in adult patients,<sup>12</sup> together with interruptions in the sleep periods that are important for patient recovery.<sup>3</sup>

The results of the present study show that in relation to the maximum noise levels, the duration of exposure to over 90 dBA was brief or inexistent (only 0.42% of the time sampled in the PICU exceeded this level). In the case of 65 dBA, the PICU registered this level 33% of the time (equivalent to about 11 h a day), followed by the NICU with 29% (equivalent to 9 h a day) and the AICU with 4% (equivalent to 1 h a day). This information evidences a risk of patient complications—a situation that is all the more critical on analyzing the time period in which the levels exceeded the recommended references, since the mean hourly noise values ( $LA_{eq,1h}$ ) exceeded the recommended limits in 100% of the measured time.

It is thus seen that the noise levels recorded in our ICUs could have an impact upon the physiological and psychological wellbeing of the patients, fundamentally as a consequence of the effects described in the literature.<sup>8</sup> The effects associated to noise are subjective and depend on the individual and disease condition involved. It should be noted that the risk of hearing loss or damage is further increased in newborn infants due to the change in environment and their inherent biological vulnerability, since these patients are removed from the safety of the mother to hostile surroundings that increase the risk of hearing alterations.<sup>1,9,10</sup> Nevertheless, in order to establish the direct effects of

noise, studies are needed in which health professionals assess and monitor the patients during the period of time in which the noise levels are evaluated in the ICU.

Regarding the risk for the health professionals posed by high noise levels in the ICU, the recorded levels fall well short of the 90 dBA established for an 8-h period of exposure to noise in the work place<sup>30</sup> (AICU presenting 62 dBA on average, PICU 66 dBA, and NICU 64 dBA). According to Garrido Galindo et al.,<sup>7</sup> the values recorded pose a moderate to high risk of directly or indirectly affecting emotions and physiological and psychological aspects of the medical and nursing personnel—resulting in the appearance of burnout syndrome.

## Conclusions

The lowest  $LA_{eq,1h}$  values corresponded to the AICU. The values corresponding to the PICU and NICU were similar, with only some differences during certain hourly intervals. Considering the time at which different activities inherent to the Unit were carried out and the increase in noise levels observed in the figures, a series of activities such as the changing of shifts, and patient feeding were seen to exert a possible influence upon the noise levels in the ICU.

From the statistical perspective, ANOVA revealed the existence of statistically significant differences between the

acoustic parameters in the ICUs—the time of day being the variable with the strongest influence upon the variations in noise level in the Unit.

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## Conflicts of interest

The authors declare that they have no conflicts of interest.

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