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**ORIGINAL ARTICLE****Ambient Noise Levels in Acute Neonatal Intensive Care Unit of a Tertiary Referral Hospital**

Sonia R. B D'Souza<sup>1</sup>, Leslie Edward Lewis<sup>2</sup>, Vijay Kumar<sup>3\*</sup>, Ramesh Bhat Y<sup>2</sup>, Jayashree Purkayastha<sup>2</sup>,  
Hari Prakash<sup>4</sup>

<sup>1</sup>Department of Obstetrics and Gynaecological Nursing, Manipal College of Nursing, Manipal University, Manipal-576104 (Karnataka) India, <sup>2</sup>Neonatal Intensive Care Unit, Department of Pediatrics, <sup>3</sup>Department of Pediatric Surgery, Kasturba Hospital, Manipal-576104 (Karnataka) India, <sup>4</sup>Department of Speech and Hearing, School of Allied Health Sciences (SOAHS), Manipal University, Manipal-576104 (Karnataka) India

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**Abstract:**

*Background:* Advances in neonatal care have resulted in improved survival of neonates admitted to the intensive care of the Neonatal Intensive Care Unit (NICU). However, the NICU may be an inappropriate milieu, with presence of overwhelming stimuli, most potent being the continuous presence of noise in the ambience of the NICU. *Aim and Objectives:* To determine and describe the ambient noise levels in the acute NICU of a tertiary referral hospital. *Material and Methods:* The ambient noise, in this study was the background sound existing in the environment of the acute NICU of a tertiary referral hospital in South India. The ambient noise levels were analyzed by an audiologist and acoustical engineer using a standardized and calibrated Sound Level Meter (SLM) i.e., the Hand Held Analyzer type 2250, Brüel and Kjær, Denmark on a weighted frequency A and reported as dB (A). *Results:* The ambient noise levels were timed measurements yielded by the SLM in terms of  $L_{Aeq}$ ,  $L_{10}$  as well as  $L_{Aeqmax}$  exceeded the standard levels ( $L_{eq} < 45$  dB,  $L_{10} \leq 50$  dB, and  $L_{max} \leq 65$  dB). The  $L_{Aeq}$  ranged from 59.4 to 62.12 dB A. Ventilators with alarms caused the maximum amount of ambient noise yielding a  $L_{AF}$  Sound Pressure Level (SPL) of 82.14 dB A. *Conclusion:* The study has found high levels of ambient noise in the acute NICU. Though there are several measures to reduce the

ambient noise levels in the NICU, it is essential to raise awareness among health care personnel regarding the observed ambient noise levels and its effects on neonates admitted to the NICU.

**Keywords:** Ambient Noise Level, NICU, Neonates, Infants, Sound Levels

**Introduction:**

Advances in neonatal care have resulted in improved survival of neonates admitted to the intensive care of the Neonatal Intensive Care Unit (NICU). Neonates, especially the smallest of them all, the preterm infants spend prolonged periods in the NICU for their continued existence. However, the NICU may be an inappropriate milieu, with presence of overwhelming stimuli, most potent being the continuous presence of noise in the ambience of the NICU. The World Health Organization (WHO) [1] as well as other professional organizations like the American Academy of Pediatrics (AAP) committee on Environmental Hazards [2], the Environmental Protection Agency- Office of Noise abatement [3], AAP Committee on environmental health [4] and Committee to establish recommended standards for Newborn ICU design [5] have

provided guidelines and recommendations for permissible noise criteria in the NICU. Regardless of the recommendations and standards for permissible noise criteria in the NICU by various committees of repute as well as the professional organizations, the ambient noise levels in the NICU have exceeded the recommendations [6].

The AAP Committee on Environmental Hazards [2] highlights that excessive noise exposure produces deafness in neonates by damaging the organ of Corti. Most of the NICUs in India have care units in the form of open care systems to care for neonates and infants admitted to the NICU. This also makes the neonates and infants more susceptible to the ambient noise present in the environment of the NICU, unlike the infants being cared for in the incubators, though incubator care has its own shortcomings.

It is well documented in a review [7] that the ambience of the NICU has the potential to cause hearing loss, difficulty in processing auditory inputs, disrupt sleep and the physiological systems in infants. Significant exposure to the physical and care-giving intensive environment of the NICU may also contribute to developmental problems in neonates and infants, especially the preterm infants admitted to the NICU. A continuous exposure to noise at 60 dB and above also potentiates the effect of ototoxic agents and is also responsible for sleep disturbances [8].

The long-term effects of noise are demonstrated in a follow-up of a cohort of 272 infants exposed to noise of 65 dB. The results of the study revealed that ten of the surviving 128 infants had bilateral hearing loss in speech frequencies (250-8000 Hz). The study also found that four of the eight infants who had bilateral hearing loss were seriously handicapped by their hearing loss and required special education [9].

Despite several studies suggesting the ill effects due to the presence of the ambient noise and the recommended standards prescribed for noise levels in the NICU, little attention is given for measurement and containment of the ambient noise levels in the NICUs of India. The first step in understanding the problem would be to objectively measure the ambient noise levels in a NICU with a standard instrument and compare the measured ambient noise levels prevalent in the NICU with the recommended standards. This would further help in framing policies and noise reduction protocols for the NICU to reduce the ambient noise levels. The aim of the present study was to determine and describe the ambient noise levels in the acute NICU of a tertiary referral hospital.

#### **Material and Methods:**

A descriptive study was conducted after approval of the Institutional Review Committee (IRC) and the ethical approval of the Institutional Ethical Committee (IEC) of Manipal University, Manipal (UEC/14/2011). The setting of the study was the acute NICU of a tertiary referral hospital of Udupi district in South India. The AAP Policy statement of 2004, reaffirmed in 2009 [10] propose the uniform definitions of 'Levels of NICU', i.e., the three levels of NICU are classified as Level I, II and III, each described with their subcategories and corresponding capabilities to provide neonatal care within an institution. The tertiary level NICU, where the present study was undertaken is a subspecialty NICU, having continuously available personnel (neonatologists, nurses, respiratory therapists, speech/hearing personnel, paediatric surgeons, physiotherapists), and equipment to provide advanced life support like High-Frequency Oscillatory (HFO) ventilation and inhaled Nitric Oxide (NO). The current

accreditation status for the acute NICU by the National Neonatal Forum (NNF) of India is Level II B NICU, and the NICU is in the process of accreditation as Level IIIA. The NICU caters to an average of 940-1045 new admissions per year.

The NICU has a 3-tier structure, consisting of an acute NICU, an intermediate level unit and the isolation unit. The NICU has 32 care units divided for the 3-tier structure for medical attention. The acute NICU houses 20 care units, which cater for neonates in critical condition and who require intensive care, the intermediate level unit has eight care units that caters for neonates who require intermediate as well as minimum intensive care and the isolation unit has four care units to care for infants with sepsis and other communicable conditions. The acute NICU is a major unit of the tertiary level NICU, which caters to neonates who require intensive care including the preterm infants.

AAP Committee on Environmental health [4] defines noise as, “undesirable sound.” Noise is precisely defined as, “An undesirable sound that interferes with communication of voice or music and causes pain or disorder in the ear”. Whereas 'Ambient noise' is defined as “The sound levels associated with a given environment, usually composite of sounds from near and far sources, none of which are particularly dominant”[11].

The ambient noise, in this study was the background sound existing in the environment of the acute NICU, analyzed by an audiologist and acoustical engineer using a standardized and calibrated Sound Level Meter (SLM). The SLM used to measure ambient noise levels of the tertiary level NICU in the present study was the Hand Held Analyzer type 2250, Brüel and Kjær, Denmark calibrated (verified and checked) using a Sound Level Calibrator 4231 (Class 1), Brüel

and Kjær, Denmark. The verification and checking was done just before each measurement to crosscheck the output sensitivity of the SLM, i.e., to check whether the readings of the SLM read the same value as the calibration settings. If the SLM was reading the correct output then it was ensured that the SLM sensitivity was not altered. In the current study, the SLM read the desired value, each time the verification was done. The ambient noise levels were measured on a weighted frequency A and reported as dB (A). For the Sound Level Meter (SLM), to mimic the receptive characteristics of the human ear an 'A-weighting filter' is incorporated in it. The A-weighting filter de-emphasizes the low frequencies produced, which are inaudible to the human ear. The Sound Pressure Level (SPL) intervals between 40 dB (A) and 140 dB (A) were set in the SLM prior to the measurements. The decibel (dB) scale is defined as, “A logarithmic scale that uses the hearing threshold of 20  $\mu$ Pa as the reference level, defined as 0 dB” [11].

The SLM generated a time-measured data set in the form of  $LA_{eq}$ ,  $L_{10}$  with ranges of  $L_{AFmax}$  and  $L_{AFmin}$ . The LAF (SPL) was reported for equipment noise in the NICU. The sound level measurements for a certain period were measured in terms of  $LA_{eq}$  i.e., Equivalent Continuous Sound levels defined as “The equivalent steady (dB A) noise level which in a stated period would contain the same noise energy as the time-varying noise during the same time period”[3]. The  $L_{10}$  was the time varying dB A defined as “The time-varying dB A level which will be expected 10% of the time during a specific measurement period.” The  $L_{AFmax}$  was the maximum time-weighted sound levels defined as “The maximum dB A sound level of < 1 second in duration during a measurement

period” and the  $L_{AFmin}$  was the minimum time-weighted sound levels defined as “The minimum dBA sound level of <1 second in duration during a measurement period” [11]. The instantaneous measured parameter viz., LAF (SPL) that denotes maximum levels of sound from equipment used in the acute NICU during the period of measurement was checked and reported.

Sequential measurements of ambient noise levels in the acute NICU were carried out for a period of one week (12 pm to 8 pm). Only the ambient noise levels in the acute NICU were measured since the neonates admitted to the acute NICU are most sensitive and vulnerable to the effects of noise. The sampling period also lasted only for seven days, since the averages taken were representative. A smaller period of assessment would also help to minimize the Hawthorne effect attention bias, [12] where the health care professionals and ancillary staff in the acute NICU could alter their behavior when they are aware that the study is conducted and avoid any other confounding variables to influence the study. All measurements were taken for an average of 8 hours per day. The duty rounds by staff and faculty that were conducted in the morning (9 am to 11:30 am) were not taken into account, since the ambient noise measurements were carried out after the completion of the rounds. The other regular rounds during change of shifts and handing-over by the nursing staff and the duty doctors were carried out as usual during the period of measurement. There were shift duty changes as well as handing over conducted by the nursing staff that occurred in the afternoon (1:30 to 2 pm) and in the evening (7:30 to 8 pm). There were an average of 9-10 nursing staff on duty during each shift and a staff to patient ratio of 1:2 was maintained throughout the period of the study; however, for neonates who were intubated a ratio

of 1:1 was maintained. There were three duty doctors and three faculty on duty during each shift. The study findings were ambient noise levels, which were reported as time-measured data generated by the SLM in the form of  $LA_{eq}$ ,  $L_{10}$  with ranges of  $L_{AFmax}$  and  $L_{AFmin}$ . The findings of the study were descriptive in nature and therefore no inferential statistics were carried out.

### Results:

#### Description of the Physical Structure of the Acute NICU:

The dimensions of the acute NICU of the tertiary referral hospital are 21.71 m x 12.84 m x 5.62 m. The acute NICU can accommodate a maximum of 20-25 neonates at any given time, since there is provision to add an additional five non-warmer care units to the 20 existing care units. The average occupancy in the acute NICU is 15-20 neonates/neonatal admissions per day. The NICU belonging to the pediatrics department of the tertiary referral hospital is catering to the population of Udupi district, Karnataka, South India.

The occupancy of neonates during the period of measurement of ambient level of noise in the acute NICU for the present study was 16, which was representative of the average occupancy in the NICU throughout the year. The acute NICU has three blocks, the right block as one enters the NICU, receives exclusively intramural births, the left block receives extramural births and the middle block houses a mix of neonates ranging from relatively stable neonates to some intramural births. The blocks do not have complete solid wall partitions but are still separated only by a half solid wall that have lofts projected on either side of the walls for the purpose of accommodating the infusion pumps, monitors etc.

### Description of LAF (SPL) for the Equipment/ Gadgets Used in the Acute NICU:

There were twelve physiological monitors functioning in the acute NICU during the period of assessment, which were wall mounted and connected via a network to the central monitoring station kept in the nurses' station. In addition, to these there were four independent portable monitors that were functioning during the period of measurement.

Noise levels for each of the equipment used in the acute NICU, were checked with the microphone of the SLM kept at a distance of 15 centimeters from each of the equipment and then the combined sound level was calculated. No modifications were done with regard to the alarms of each of the equipment before or during the measurement. The LAF (SPL) of the physiological monitors, ventilators and other equipment used in the acute NICU during the period of ambient noise measurement for a period of one week are described in table 1, which show that ventilators with alarms caused the maximum amount of noise yielding a LAF (SPL) of 82.14 dB A. On the other hand, equipment like the nebulizers, hand driers as well as ventilators without alarms also generated noise that exceeded 70 dB A. In the present study, the HFO Ventilator was not in use during the period of measurement, but found that all ventilators with or without alarms had LAF (SPL) that exceeded 70 dB. Only the physiological monitors without alarms yielded a LAF (SPL) of 52.42 dB A.

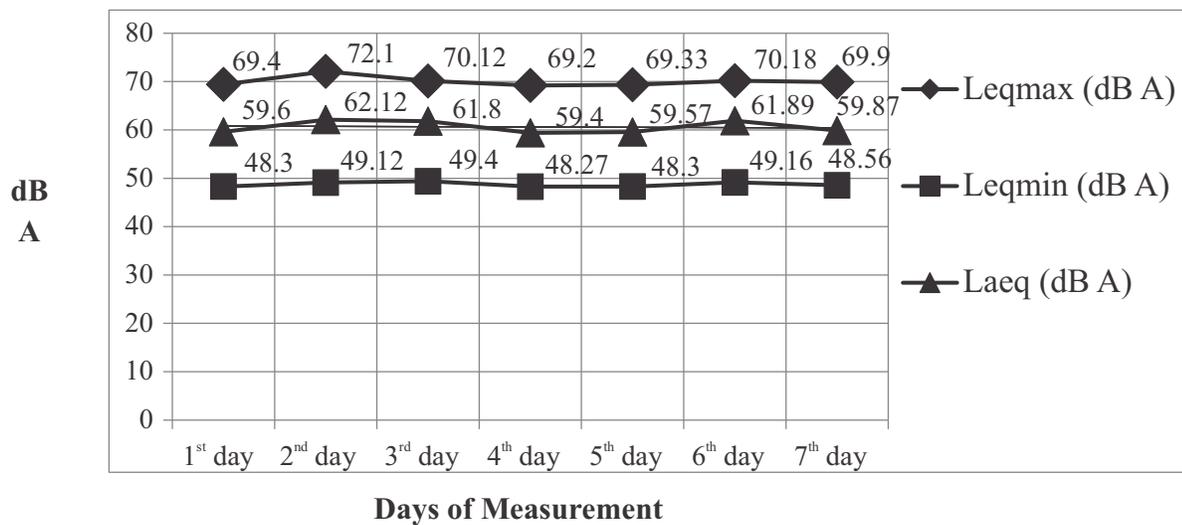
### Sequential Measurements of Ambient Noise Levels in the Acute NICU for a Period of One Week:

Timed measurements, done using the SLM yielded data in the form of  $LA_{eq}$  and ranges of  $L_{AFmax}$  and  $L_{AFmin}$ , as well as  $L_{10}$  that were used for describing the ambient noise levels in the acute NICU. The data was done sequentially for all the blocks of the acute NICU. Prior to the measurements, the SPL intervals were set between 40 dB (A) and 140 dB (A) in the SLM. The  $LA_{eq}$  and the corresponding range of  $L_{AFmax}$  and  $L_{AFmin}$  are depicted in figure 1, show that the maximum hourly equivalent sound i.e.,  $LA_{eq}$  of 62.12 dB A was found on the 2nd day of the measurement that was carried out for a week's time. Whereas the lowest was recorded on the 4<sup>th</sup> day which was 59.4 dB A, whereas the maximum noise level i.e.,  $L_{eqmax}$  registered in the acute NICU was 72.1 dB A and the minimum noise level i.e.,  $L_{eqmin}$  was 48.27 dB A. The  $LA_{eq}$  ranged from 59.4 to 62.12 dB A.

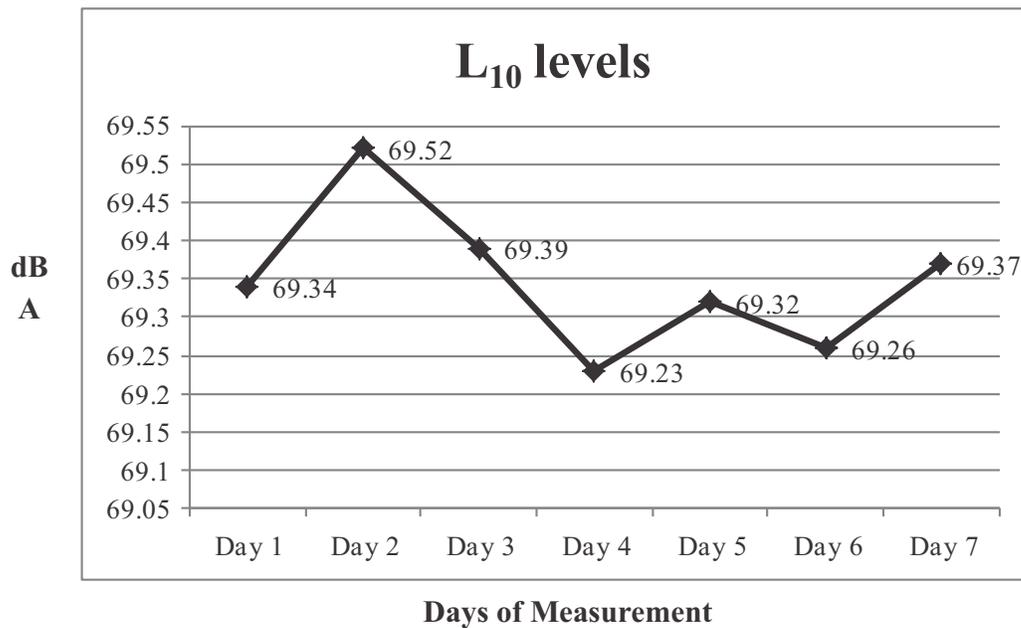
Further, the study also attempted to examine the  $L_{10}$  levels known as the 'Time varying dBA', which depicts the sound levels expected 10% of the time during a specific measurement period. The  $L_{10}$  levels are depicted in figure 2. All the  $L_{10}$  are  $\geq 69$  dB A, with the second day registering a maximum of 69.52 dB A. All the values of  $LA_{eq}$ ,  $L_{10}$  as well as  $LA_{eqmax}$  exceeded the recommended levels of permissible noise [5] ( $L_{eq} < 45$  dB,  $L_{10} \leq 50$  dB, and  $L_{max} \leq 65$  dB).

**Table 1:  $L_{AF}$  (SPL) of the Equipment Functioning in the NICU during the Period of Measurement of Ambient Noise in the NICU**

Equipment	Functioning Units	$L_{AF}$ (SPL)
Ventilators	3	71.56 dB A
Ventilators with alarms	2	82.14 dB A
Physiological monitors	9	52.42 dB A
Physiological monitors with alarms	7	68.62 dB A
Infusion pumps	6	68.40 dB A
Syringe pumps	8	65.34 dB A
Phototherapy units	8	60.46 dB A
Nebulizer	1	70.26 dB A
Hand drier	2	70.22 dB A



**Fig. 1:  $L_{Aeq}$  with Range of  $L_{Aeqmax}$  and  $L_{Aeqmin}$  in the Acute NICU during the Measurement Period of One Week**



**Fig.2: L<sub>10</sub> Distribution in the Acute NICU for the Period of One Week**

### Discussion:

The present study confirms the results of a study conducted by Livera *et al.* [13] in a NICU in India, who assessed noise of the NICU by spectral analysis and found that ventilators and incubators with alarms generated a maximum noise of 83 dB SPL. Another study conducted after a year in the same setting, found that the Nebulizer caused LA<sub>eq</sub> of 69.74 dB A, whereas, the present study found LAF (SPL) of 70.26 dB A for the Nebulizer. This study had also found that the HFO Ventilator generated LA<sub>eq</sub> of 60.20 dB A [14]. In the present study, the HFO Ventilator was not in use during the period of measurement, but found that all ventilators with or without alarms had LAF (SPL) that exceeded 70 dB A, implying that equipment contributes to noise exceeding the recommendations in the ambience of the NICU.

The results of the study also show that the hourly equivalent sound (LA<sub>eq</sub>) exceeded the recommendations of the Sound Study Group

(SSG) [3]. The results also refute the permissible noise criteria of hourly LA<sub>eq</sub> of 50 dB A for neonatal nurseries meant to cater for hospitalized neonates [15]. The present study reaffirms the results of a plethora of studies that have measured the background noise levels in the NICUs around the world and found that the noise levels in the NICUs exceeded the recommendations [16-19].

The ambient noise levels in the setting of the present study are found to exceed the recommendation by AAP that noise level in the NICU should not exceed 45-50 dB [4] and the US committees in collaboration [3, 5, 20] that recommend, "Daytime average noise level of < 45 dB in the NICU" as well as the WHO recommendation of 35 dB A [1]. The ambient noise levels in the NICU in this study are congruent with another study that conducted weekly sound survey's and found that peak sound of two modern NICUs of two different hospitals

was >90 dB at significant levels ( $p < 0.001$ ) [21].

The results of present study are also in line with yet another trial that assessed the mean levels and the range of noise measured in the NICU and found that the ventilator room had noise levels ranging from 61.15 dB to 72.48 dB with mean levels of 69.99 dB and preterm room 53.62 dB - 59.52 dB with average levels of 57.12 dB [13].

An important recommendation by the committee to establish recommended standards for newborn ICU design [5, 20] is that hourly  $L_{eq} < 45$  dB,  $L_{max}$  to be  $\leq 65$  dB and  $L_{10} \leq 50$  dB. All the values of  $LA_{eq}$ ,  $L_{10}$  as well as  $LA_{eqmax}$  exceeded the recommended levels in the present study. A similar study to assess the sound levels in a NICU in Iran [22] also found that the mean values of  $L_{eq}$ ,  $L_{10}$ , and  $L_{max}$  were 63.46 dBA, 65.81 dBA, and 71.30 dBA, respectively, which are congruent with findings of the study. Yet another study conducted to characterize noise levels in a NICU in Spain also found similar results when the maximum noise levels measured for critical unit of the NICU were 88.8 dBA [23].

A limitation of this study was that the health care professionals and the ancillary staff were aware of the ambient noise level measurements done in the acute NICU, which may have affected their behavior and could affect the results of the study.

In addition, this study measured SPL levels for an average of 8 hours per day. In addition, this study took into account the ambient noise levels that occurred during the afternoon and evening shifts in the acute NICU and the ambient noise levels in the morning shift and the night shift were not studied. Further research should focus on measuring ambient noise levels for 24 hours per day to obtain a clear picture of ambient noise levels. Likewise, ambient noise measurements should be a continuous process, wherein SLMs are fixed permanently in the NICU and feedback given to health professionals regarding the ambient noise level measurements. This may sensitize the health care professionals to modify their behavior and their actions with regard to containment of noise in the NICU.

### Conclusion:

The study has found high levels of ambient noise in the NICU. Though there are several measures to reduce the ambient noise levels in the NICU, it is essential to raise awareness among health care personnel regarding the noise present in the ambience of the NICU and its effect on the neonates admitted to the NICU.

**Source of Funding:** Indian Council of Medical Research (ICMR)

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\*Author for Correspondence: Dr. Vijay Kumar, Department of Pediatric Surgery, Kasturba Hospital, Manipal-576104, Karnataka, Email: vijay.kumar@manipal.edu Cell: 0820-2922776