Original Article

Ambient noise and neonatal hemodynamics - An observational cross-sectional study

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ABSTRACT

Background: Previous studies reported numerous adverse effects of noise in the newborns such as increase in the heart rate (HR) and respiratory frequency and drop in the oxygen saturation. **Objective:** The objective of this study was to study the effect of ambient noise levels in neonatal intensive care unit (NICU) on the hemodynamics of neonates**. Materials and Methods:** This was a hospital-based cross-sectional observational study which aimed at assessing the ambient noise levels in the NICU with a digital decibel meter and its effect on HR, respiratory rate (RR), and oxygen saturation. A total of 105 neonates (both preterm and term) having stable cardiorespiratory status were enrolled in the study. **Results:** The mean noise level recorded in the NICU was 56.2 dB. The lowest noise level was recorded at 8 am, that is, 46 dB while the highest recorded level was at 2 pm, that is, 65 dB in different areas of the NICU. There was a statistically significant increase in the HR in relation to the noise levels at all times ($p<0.0001$). The RR also showed a significant rise in relation to the increase in noise level ($p<0.0001$ at 2 pm with maximum noise level). The oxygen saturation showed a negative correlation and a statistically significant drop at 2 pm when maximum noise level was recorded ($p<0.0001$). Changing shifts and more number of healthcare personnel were important factors contributing to increased noise levels at 2 pm. **Conclusion:** Noise levels of >56 dB affected the hemodynamics of the newborn. The maximum increase in the mean HR, RR, and drop in saturation was observed at 2 pm. Staff sensitization and attitude change are needed to decrease the noise pollution in NICU.

Key words: *Ambient noise levels, Decibel meter, Hemodynamics*

Improvement in the health-care services in neonatal intensive care units (NICUs) has improved neonatal survival. The use of technology to care for newborns has also transformed NICU into very noisy places [1]. Fetuses born after 24 weeks have almost complete cochlea and sensory organs and can perceive sound. When fetuses are born too early, they leave the silent atmosphere of the uterus and enter the noisy environment of the NICU [2].

The literature review from previous studies reported numerous adverse effects of noise in the newborns such as increase in the heart rate (HR) and respiratory frequency and drop in the oxygen saturation. Central nervous system's immaturity and inability to cope with stress due to decreased autonomic and self-regulatory abilities make preterm neonates more susceptible to negative effects of environmental stimuli [3,4]. It causes alterations in their motor activity and behavioral problems (excessive crying and agitation). Long-term sequelae can be hearing loss [5,6].

Maintenance of ambient noise levels in the NICU within the permissible range supports the neonatal physiologic stability. It improves weight gain and sleep pattern and reduces the duration of the hospital stay. It reduces potential adverse effects on the auditory development of premature neonates and complications with hearing and comprehension. It also enhances brain development in later stages of life. There are very few studies which assessed the effect of ambient noise on neonatal hemodynamics; therefore, this study was planned to assess the ambient noise levels in the NICU and to correlate its effect on the hemodynamics and to assess the intrinsic and extrinsic variables that would influence the noise levels in NICU.

MATERIALS AND METHODS

This was a cross-sectional study conducted at a tertiary care centre over a 2 years period from July 2015 to September 2017. Institutional ethics committee approval was obtained and informed parental consent was taken. The hospital has 16-beds, level 3(A) NICU, which is situated at the second floor of the hospital building having an area of 50 × 29 square feet. Monthly on an average, 60 babies are admitted which includes inborn and outborn babies. There are three cubicles where neonates are stationed and nurse-to-patient ratio at any given shift is 1:2. It has tile flooring, brick walls, and concrete roof and has glazed, soundproof window panes. Next to NICU is the corridor, utilized for entry and exit

from NICU by NICU graduate's parents, relatives, health-care professionals, and teachers. This corridor is separated from the NICU by double door area. There is air-conditioning available in the NICU, and there are no major transport roads surrounding the NICU. The bed occupancy at the time of the study was 80%.

The sample size was calculated as follows: Assuming 43% of neonates were negatively affected by the noise, at 95% confidence interval with 10% margin of error, the sample calculated was 95. Using Winpepi software and considering 10% dropouts, 105 neonates were enrolled for the study. Inclusion criteria were as follows: Neonates admitted in NICU of >32 weeks of gestation, birth weight >1800 g, and with stable cardiorespiratory status (HR 120–160/min, respiratory rate (RR) <60/min, and peripheral capillary oxygen saturation (SpO2) 88–92% for preterm and 94–96% for term, not requiring any respiratory or inotropic support). Babies who were <32 weeks of gestation, weighing <1800 g, with congenital development anomalies, sick newborns (ventilated, hypoxic-ischemic encephalopathy, and sepsis), and parents not agreeing to enroll their babies for the study, were excluded from the study.

The neonates fulfilling the inclusion criteria were further evaluated and their demographic details were recorded as per the structured pro forma. A thorough physical examination was performed to rule out the exclusion criteria and the baseline hemodynamics. The sound levels were measured with a decibel meter at 8 am, 2 pm, and 8 pm in all three cubicles of the NICU and mean value of recordings was taken. The decibel meter that was used has been designed to meet the measurement requirement in health-care areas (instrument specifications: Measuring range 30 dB–130 dB, accuracy ±1.5 dB, frequency range 31.5 Hz–8.5 KHz, and sample rate 2 times/s). The corresponding HR, respiratory rate, and oxygen saturation of the enrolled newborns at that time were documented. Each enrolled neonate was assigned one separate multipara monitor which used Masimo technique for recording and the same multipara monitor was used for the entire length of stay of the baby. The study observer reviewed all the recordings at each shift and an average of HR, RR, and SpO2 was taken.

The data was collected and analyzed using the Statistical Package for the Social Sciences Version 17 for Windows. The demographic variable, mode of delivery, and hours of life after birth were calculated as number and percentage. Analysis of variance (ANOVA) test was used to find out significant difference of noise level according to time, significant difference of HR, RR, and SpO2 according to noise level at 8 am, 2 pm, and 8 pm, respectively. Correlation coefficient was used to find the correlation between noise level and HR, RR, and SpO2 at 8 am, 2 pm, and 8 pm, respectively. $p<0.05$ was accepted as the level of statistical significance.

RESULTS

A total of 130 babies were approached for the enrolment, 10 declined, five were excluded because their septic screen came positive and they became unstable during the course of the study, 10 left against medical advice. The demographic details of the study neonates were as shown in Table 1. Most of the neonates enrolled were term neonates born of vaginal delivery weighing >2.5 kg.

The record of ambient noise levels in the NICU demonstrated fluctuations at different times of the day. The ambient noise levels in the NICU at 8 am and 8 pm ranged between 46 dB and 62 dB, whereas, at 2 pm, it ranged between 55 dB and 65 dB. The mean noise level at 8 am was 55.43±3.07 dB, at 2 pm was 58.19±3.50 dB, and at 8 pm was 55.58±3.16 dB. Table 2 shows the comparison of mean noise levels at different times in the NICU. The maximum noise levels were observed at 2 pm (58.19±3.50 dB). The mean difference in noise levels compared with different times of the day was analyzed quantitatively using ANOVA test and found to be statistically significant ($p<0.0001$).

The values of mean HR, RR, and oxygen saturation at 8 am, 2 pm, and 8 pm, when the noise levels were between 46 and 65dB, are depicted in Tables 3-5, respectively.

There was a statistically significant increase in the HR at 8 am, 2 pm, and 8 pm when the noise levels were between 46 dB and 65 dB. The increase in RR and drop in SpO2 were statistically

Table 1: Demographic details of neonates

Parameters	Number of neonates n=105 (%)
Mode of delivery	
LSCS	44 (41.9)
Normal	61 (58.1)
Gestational age	
32.1–36.6	11 (10.5)
37 and above	94 (89.5)
Sex	
Male	58 (55.24)
Female	47 (44.76)
Birth weight	
1.8–2.5 kg	47(44.76)
>2.5 kg	58 (55.24)

LSCS: Lower segment cesarean section

Table 2: Comparison of mean noise levels at different times in the NICU

Time	Noise level (dB)	
	Range (dB)	Mean±SD
At 8 am	46–62	55.43±3.072
At 2 pm	55–65	58.19±3.500
At 8 pm	46–62	55.58±3.162

F=23.96; p<0.0001, NICU: Neonatal intensive care unit, SD: Standard deviation

Table 3: Comparison of mean HR, RR, and SpO2 according to noise level at 8 am in the study group

Noise level (dB)	HR/min	RR (min)	SpO2 (%)
	Mean±SD	Mean±SD	Mean±SD
46–50	132.16±5.565	34.16±2.939	96.48±1.122
51–55	134.31±7.296	35.46±3.929	96.31±1.182
56–62	138.18±6.557	36.43±4.377	95.90±1.195
F value	8.66	2.94	2.51
p value	<0.0001	0.057	0.086
Mean % change	2.88	2.74	0.43

SpO2: Peripheral capillary oxygen saturation, SD: Standard deviation, HR: Heart rate, RR: Respiratory rate

significant only at 2 pm when the noise levels fluctuated between 55 dB and 65 dB. A correlation between the HR, RR, and oxygen saturation with noise levels at different times demonstrated the results as shown in Table 6.

There was a statistically significant increase in the HR in relation to the noise levels at all times (p<0.0001) as seen in Table 6. The RR also showed a significant rise in relation to the increase in noise level. The oxygen saturation showed a negative correlation and a statistically significant drop at 2 pm when maximum noise level was recorded.

DISCUSSION

NICUs have proven to be a boon for the survival of preterm and sick neonates, but they are also places of enormous stress, the most potent being the continuous presence of noise. It is observed that the noise levels in the NICU are louder than most homes and offices, which include high noises of short duration and at irregular intervals. Apart from the short-term changes in hemodynamics and sleep states, the long-term effects of noise pollution on neonates include elevated blood pressures, psychological effects such as annoyance/isolation and sleep disturbance and affect mental health as well as cognitive ability such as disturbances in reading, concentration, memory, and attention [7].

To the best of our knowledge, our study is the first clinical study evaluating the effect of ambient noise on neonatal hemodynamics, in India. The present study assessed the effect of noise on the hemodynamic variables such as respiration, HR, and oxygen saturation. The mean noise level in the NICU during the study period was 56.2 dB that was higher than that which is recommended by the American Academy of Pediatrics (45 dB) and the World Health Organization guidelines (30 dB). Cardoso *et al.* [14] reported a mean noise level of 58.62 dB in their study. This study demonstrated that noise levels were highest at 2 pm.

The fluctuations of noise levels in the NICU, in the present study, varied at different times of the day. The minimum and maximum noise level at 8 am and 8 pm were between 46 dB and 62 dB, whereas this ranged between 55 dB and 65 dB at 2 pm. Bremmer *et al*. [8] in their study also reported that the average sound level in dB in the NICU varied between 50 dB and 140 dB for various activities and interactions. The noise levels were significantly high at 2 pm as compared to at 8 am and 8 pm. The mean noise level recorded at 2 pm was 58.19 dB as compared to 55.43 dB at 8 am and 55.58 dB at 8 pm (Table 2). This was attributed to more number of doctors, nursing personnel, and helpers in NICU during changing duty shifts. Nursing interventions and conversation between health-care professionals, cleaning protocols being undertaken by the attendants added to the noise levels.

In terms of minimum, maximum, and average noise levels recorded, many studies in NICU reported a wide range of values ranging between 36 dB and 80 dB [9]. Changing shifts and more number of health-care professionals present in the NICU was also observed as a cause of loud noise in other studies. Joshi and Tada analyzed noise levels in NICU of urban hospital and found that the range of noise generated in NICU was between 50 dB and 95 dB. They also reported that the noise levels were maximum during the morning shifts as compared with other shifts [10]. Pinheiro *et al*. identified sound pressure level at the NICU. They showed that the noise levels in the NICU varied from 52.6 dB to 80.4 dB, maximum sound levels were during afternoon time as compared to morning and evening time [11].

Exposure to high noise levels can have negative physiologic responses among neonates such as fluctuations in HR, RR, and oxygen saturation. The percentage increase in mean HR was 2.88%, 7.65%, and 4.41% at 8 am, 2 pm, and 8 pm, respectively. There was a statistically significant (p<0.0001) correlation of

Table 4: Comparison of HR, RR, and SpO2 according to noise level at 2 pm in the study group

Noise level (dB)	HR/min	RR (min)	SpO2 (%)
	Mean±SD	Mean±SD	Mean±SD
55–55.9	135.58±6.239	35.37±2.910	94.68±1.416
56–60	141.09±6.182	38.55±4.331	94.61±1.549
60.1–65	145.95±8.829	41.55±4.228	93.14±1.612
F value	11.80	11.62	8.16
p value	<0.0001	<0.0001	0.001
Mean % change	7.65	17.47	1.63

SpO2: Peripheral capillary oxygen saturation, SD: Standard deviation, HR: Heart rate, RR: Respiratory rate

Table 5: Comparison of HR, RR, and SpO2 according to noise level at 8 pm in the study group

Noise level (dB)	HR/min	RR (min)	SpO2 (%)
	Mean±SD	Mean±SD	Mean±SD
46–50	131.50±4.011	33.92±1.084	96.25±1.288
51–55	134.33±7.239	35.08±4.491	96.04±2.177
56–62	137.30±6.569	36.25±4.460	96.03±1.382
F value	5.04	1.89	0.10
p value	0.008	0.16	0.90
Mean % change	4.41	6.87	0.23

SpO2: Peripheral capillary oxygen saturation, SD: Standard deviation, HR: Heart rate, RR: Respiratory rate

Table 6: Correlation between noise level and HR, RR, and oxygen saturation

Correlation between	r value	p value
Noise level (dB) and HR/min at 8 am	0.37	<0.0001
Noise level (dB) and HR/min at 2 pm	0.42	<0.0001
Noise level (dB) and HR/min at 8 pm	0.37	<0.0001
Noise level (dB) and RR at 8 am	0.27	0.005
Noise level (dB) and RR at 2 pm	0.38	<0.0001
Noise level (dB) and RR at 8 pm	0.27	0.005
Noise level (dB) and SpO2 at 8 am	−0.14	0.17
Noise level (dB) and SpO2 at 2 pm	−0.36	<0.0001
Noise level (dB) and SpO2 at 8 pm	−0.024	0.81

SpO2: Peripheral capillary oxygen saturation, HR: Heart rate, RR: Respiratory rate

HR with increase in noise levels at different times. Wharrad and Davis studied behavioral and autonomic responses to sound in preterm and full-term babies and observed accelerations in HR were statistically significant in relation to high noise levels. The increase in HR was proportionate to the intensity of sound stimulus in term neonates [12].

The variation in respiration may range from tachypnea to apnea with increasing noise levels. The percentage change in mean RR was 2.74%, 17.47%, and 6.87% at 8 am, 2 pm, and 8 pm, respectively. The increase in RR showed a statistically significant correlation with the increase in the noise level at all times.

The oxygen saturation dropped with increasing noise levels; a statistically significant drop in oxygen saturation was noted at 2 pm when the noise levels were maximum (55–65 dB). The percentage drop in mean SpO2 level was 0.43%, 1.63%, and 0.90% at 8 am, 2 pm, and 8 pm, respectively. Similar finding was observed in a study conducted by Aly and Ahmed in which changes were identified in neonatal response, behavior, and their vital signs when newborns were exposed to noise which was recorded using sound level meter. They observed that the mean HR and RR increased and SpO2 declined due to increased noise levels [13]. Cardoso *et al*. [14] evaluated the HR and oxygen saturation in low birth weight newborns when exposed to increasing noise levels in incubators in a neonatal unit. The study demonstrated a significant difference in the mean HR. When the noise level was within agreeable limits, HR was 137.74/min, SpO2 - 95%, and with exceeding noise, it increased to 142.59 and SpO2 - 94% [14]. Long *et al.* have reported that increased noise levels caused an increase in HR and RR with a decrease in oxygen saturation [15].

Increasing noise levels in the NICU may cause apnea, hypoxemia, alteration in oxygen saturation and increased oxygen consumption secondary to increased HR and RR, and, therefore, decrease the number of calories available for growth. These changes in hemodynamics may result in poor growth, abnormal sleep patterns, and behavioral disturbances. It is also associated with inattention, language delay, attention, language performance, developmental delay, and cochlear damage resulting in hearing loss [13]. In preterm, it may lead to bronchopulmonary dysplasia, retinopathy of prematurity, intraventricular hemorrhage, and periventricular leukomalacia [15]. Noise levels measured in neonatal units are unlikely to cause hearing loss in staff but can interfere with effective staff functioning. Noise interferes with neonatal physiological stability and sleep pattern, which is related to loudness and duration of noise. Furthermore, noise levels >70 dB can cause majority of babies to wake only after 3 min and can affect growth and feeding pattern [16].

Thus, strategies to reduce noise levels in NICU will optimize the well-being of newborns during their stay in NICU and later life. The result of this study could be used to modify the extrinsic and intrinsic factors which affect the ambient noise levels. The limitations of the study include that records of continuous monitoring of noise levels were not done. Hence, transient variations in noise level and its effect on the hemodynamics could not be assessed. The difference of the influence of noise on the hemodynamics of pre-term and term was not assessed separately.

On the basis of our study results, we recommend to take steps targeted to decrease the noise levels in NICU such as periodic staff sensitization about the harmful effects of loud noise on neonates. Additional measures include lowering the voice while talking, taking over away from the patient and avoiding overcrowding during duty shifts and no touch policy when the neonate is in deep sleep. Internal noise should be reduced or eliminated by minimizing the volume of alarms of the equipment in NICU, padded doors and soundproof window panes, and use of door stoppers. The ears of neonates can be protected by providing earmuffs. All health-care professionals should adopt policies of developmentally supportive care in NICU settings.

CONCLUSION

The maximum noise level was recorded in the afternoon shift (55–65 dB) which was accounted to change of shift of professionals, more number of health-care professionals present and conversations among them. Noise levels of >56 dB affected the newborns in their vital parameters.

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