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RESEARCH

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Sound levels and its effect on physiology of low birth weight newborns in a special care newborn unit — a prospective observational study

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Abstract

Background From quiet environment in uterus, neonates in special care newborn units (SCNU) get exposed to a stressful technology-driven environment. Noise level in neonatal intensive care units (NICU) depends on social and psychological realm of people working there. In NICU, an hourly L_{eq} (median equivalent continuous sound level) of sound should be 45 dB, L_{max}, 60 dB, and L_{10} not exceeding 50 dB (AAP, 2007). Noise level in SCNUs of northeast India has not been studied.

Aim Create awareness among health workers (HW) regarding noise.

Objective To study (a) noise level in special care newborn unit and (b) its effect on neonatal physiology.

Methodology A prospective observational study was conducted in a teaching hospital in northeast India for 1 month. After IEC approval, ambient sound levels in intensive care unit (ICU) (levels 2 & 3) and kangaroo mother care (KMC) area were measured using inVH by Bosch Engineering Solution (android app) in 3 shifts. Forty hemodynamically stable quiet low birth weight neonates (level 2: 16, level 3: 14, KMC: 10) were evaluated for heart rate and respiratory rate at same time. Acutely sick neonates were excluded. Statistical analysis was done using SPSS.

Results Average sound at 10 am, 5 pm, and 11 pm in level 2 was 70.2 (+3.78) dB, 71.9 (+4.21) dB, and 54.6 (+5.38) dB; in level 3: 66.4 (+3.71) dB, 64.9 (+3.88) dB, and 63.5 (+2.52) dB; and KMC: 55.06 (+5), 54.66 (+5.38), and 47.7 (+5.1) dB ($p=0.0052$). Of included neonates, mean birthweight in intensive vs KMC area was 1.378 (+0.017) vs 1.337 (+0.02) kg ($p=0.1$) and gestational age 35.45 (+0.25) weeks and 34.8 (+0.91) weeks ($p=0.2$). The mean neonatal heart rate and respiratory rates in level 2 were 154/min and 44 cycles/min, level 3: 148/min and 47 cycles/min; and KMC: 124/min and 40 cycles/min.

Conclusion Significant noise pollution is detected in levels 2 and 3 neonatal intensive care units and minimal in kangaroo mother care area. Raised neonatal heart rates and respiratory rates in intensive care units with respect to KMC area may be related to noise. The social and psychological realm of healthcare workers and caregivers needs urgent improvement so as to reduce ambient noise pollution in special care newborn units.

Keywords Noise, Decibels, Neonates, Newborn, Neonatal intensive care unit, Special care newborn unit

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Background

Noise pollution in SCNU is often an overlooked entity. From a quiet environment in uterus, neonates in SCNU get exposed to a stressful technology-driven environment. The self-generated sound of infant crying can be a significant source of noise as loud sounds tend to be amplified within the incubator. The American Academy of Pediatrics (1997) recommended that safe sound levels in the NICU should not exceed 45 dB on an A-weighted scale in hourly level (dBA). Noise level in NICU depends on social and psychological realm of people working there. In NICU, an hourly LEQ (mean equivalent continuous sound level) of sound should be 45 dBA, Lmax (maximum sound level), 60 dBA, and L10 (sound level exceeded for 10% of the total time of measurement) not exceeding 50 dB (AAP, 2007) [1].

Noise levels of SCNUs of northeast India has not been studied. It is well established that noise levels in the NICU often exceed these recommendations (exceeding 45 dBA), potentially resulting in numerous adverse noise-induced health effects which include and not limited to behavioral disturbances, increased muscle tension, alteration in vital parameters including heart rate, respiratory rate, oxygen saturation, blood pressure, and intracranial pressure. However, the effects of excessive noise exposure on the brain and long-term developmental outcomes are not well established [2].

Noise pollution within the neonatal care units arises from various sources: from alarms and jingles of life support apparatus including monitors and ventilators, suction apparatus, warmers, infusion systems loud voices, and medical and family visits; handling of incubators; careless handling of equipments and furniture; and air-conditioning and multiple other sources [3].

The aim of the current study is to create awareness among health workers (HW) regarding noise pollution in NICU. The secondary objectives of this study are to detect the noise levels in SCNU and its effect on neonatal physiology.

Fig. 1 Android application iNVH by Bosch

Methods

An observational study was conducted in a teaching hospital in northeast India for 1 month. After IEC approval (approved on IEC meeting held on 3rd March 2022, vide letter no. SMC/2826, date — 6th February 2023), ambient sound levels in ICU (levels 2 & 3) and KMC area were measured in decibels (dB) using “iNVH” open-source android application by Bosch Engineering Solution (Figs. 1 and 2) in 3 shifts everyday at 10 am, 5 pm, and 11 pm.

Forty hemodynamically stable (not requiring ventilatory or ionotropic support) quiet LBW neonates (level 2: 16, level 3: 14, KMC: 10) were evaluated for heart rate and respiratory rate at the same time. All hemodynamically stable LBW neonates of both preterm and term gestation are included. Neonates with life-threatening congenital anomalies and neonates on life support were excluded from the study.

Level 2 ICU holds and provides intensive care for sick and premature infants (premature more than 32 weeks and low birth weight above 1500 g). Level 3 ICU provides comprehensive care for more seriously ill neonates, while kangaroo mother care unit is for the babies who have been moved from intensive care to regular nursery care.

Fig. 2 Real-time user interface of iNVH

Table 1 Mean birth weight and mean gestational age in babies of intensive care unit and KMC unit

	Mean birth weight	Mean gestational age
Intensive unit	1.378 kg (+0.017)	35.45 (+0.25) weeks
KMC unit	1.337 kg (+0.02)	34.8 (+0.91) weeks
	$p=0.1$	$p=0.2$

Statistical analysis done using SPSS, 3-way ANOVA tests, and *t*-tests was done to analyze the mean noise intensities, mean heart rates, and respiratory rates.

The above Figs. 1 and 2 show the user interface of inVH application; this application uses the inbuilt microphone of any smartphone and automatically measures the ambient noise levels with parameters in decibels Linst (the instantaneous fluctuating noise level), Lmax (maximum sound level), Lmin (minimum sound level), and LEQ (mean equivalent continuous sound level) over the period of measurement, sound levels were ideally measured for the whole duration while examining and noting the vital parameters of the neonates in each session, and the machine automatically calculated the mean equivalent noise intensity.

Results

The recorded mean birth weight and the mean gestational age of the babies are as depicted in Table 1.

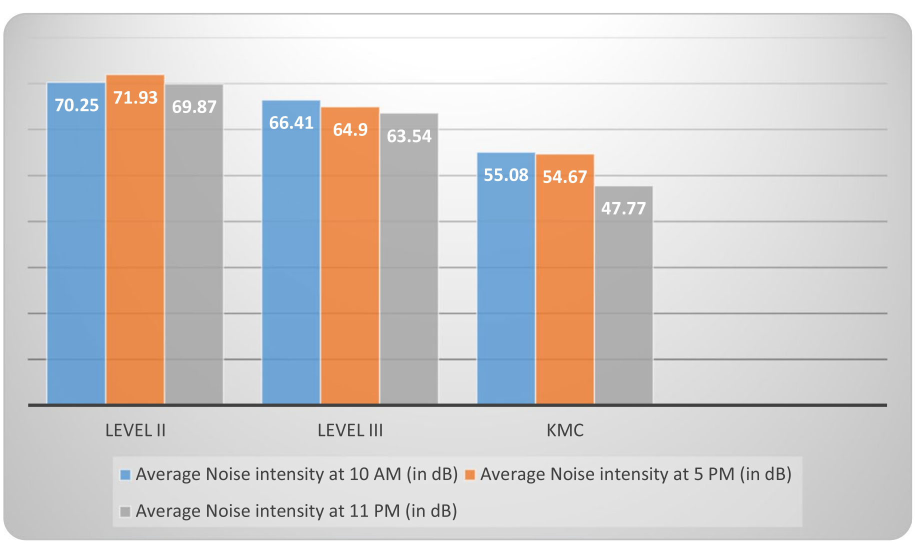

Fig. 3 Graphical representation showing average noise intensities at different newborn care units

The following Fig. 3 shows the average noise intensities noted in different levels of inpatient units at 3 different shifts. The noise level in level 2 and level 3 nursery is significantly more than the safe permissive level for newborn. No diurnal variation in noise level is noted. Average noise at 10 am, 5 pm, and 11 pm in level 2 was 70.2 (+3.78) dB, 71.9 (+4.21) dB and 54.6 (+5.38) dB; in level 3: 66.4 (+3.71) dB, 64.9 (+3.88) dB and 63.5 (+2.52) dB; and KMC: 55.06 (+5), 54.66 (+5.38), and 47.7 (+5.1) dB with $p=0.0052$ by ANOVA test (significant at $p<0.05$).

The following Table 2 depicts the average heart rates and respiratory rates measured at different time frames in level 2, level 3, and KMC units. High noise level in the NICU disturbs the sleep pattern and keeps the babies restless and irritable. KMC unit has the least noise level, and babies enjoy undisturbed sleep.

With the above qualitative data showing mean heart rates and respiratory rates, we did both 3-way ANOVA and t-test to check significance. For heart rates, the F-statistic for 3-way ANOVA is 29.06, and p-value is 0.008 (<0.05 significant). And on T-test, there was no significant difference ($p>0.5$) between level 2 and level 3 neonatal ICU with t-value of 0.71 and the p-value 0.25.

However, on comparing level 2 with KMC, the t-value is 5.94529. The p-value is 0.002, and the result is significant at $p<0.05$. And in plotting level 3 with KMC, the t-value came out to be −8.01784, and the p-value is 0.0006 (significant at $p<0.05$), denoting a statistically significant impact of noise on infant heart rate.

In further comparison of respiratory rates of the newborns in various levels of care, the F-statistic for 3-way ANOVA is 4.87, and p-value is 0.05 (not significant).

But on comparing mean respiratory rates of level 2 with KMC and level 3 with KMC separately using Student's t-test, we found t-values of 4.02 and 2.68 and p-values of 0.007 and 0.027, respectively, both significant at $p<0.05$, thus signifying effect on noise and on increasing respiratory rates and heart rates in different neonatal care units.

The mean noise intensity measured in the NICU in daytime, afternoon, and night was 65.25 dB, 67.93 dB, and 64.87 dB, respectively, which was significantly higher than the prescribed limit of 45 dB. And there is a significant difference in noise intensities of level 2/3 NICU and KMC unit ($p<0.05$). Maximum noise intensity recorded was 74 dB, while the minimum intensity was 58 dB in the NICU.

Discussion

In a 1997 position statement, the American Academy of Pediatrics (AAP) summarized the impact of noise on the developing fetus and neonate and recommended that average sound levels in the NICU should be less than 45 dBA [1, 2].

The existing analyses of the acoustic environment in the NICU indicated that the recommended noise standards are being flouted regularly. Different NICU environment acoustic level studies have shown that the mean noise levels range from 48 to 55 dBA and 53.9 to 60.6 dBA [4, 5]. This correlated well with our study where we found the average sound at 10 am, 5 pm, and 11 pm in level 2 was70.2 (+3.78) dB, 71.9 (+4.21) dB, and 54.6 (+5.38) dB; in level 3: 66.4 (+3.71) dB, 64.9 (+3.88) dB, and 63.5 (+2.52) dB; and KMC: 55.06 (+5), 54.66 (+5.38), and 47.7 (+5.1) dB, with significant variation among the results ($p=0.0052$). Maximum noise intensity recorded was 74 dB, while the minimum intensity was 58 dB in the NICU.

Numerous studies have demonstrated the adverse effects of the acoustic environment in the NICU by examining the relationship between acoustic events and alterations in infant physiologic state. Studies have demonstrated that high intensity, transient noises are associated with behavioral disturbances and increases in infant muscle tension. Other studies have documented a relationship between acoustic noise and changes in infant vital signs including heart rate, respiratory rate, O2 saturation, blood pressure, and intracranial pressure [2, 3].

A study done in Turkey which included both questionnaire and objective sound level measurement found out the sound level to be frequently above 45 dB in neonatal ICUs leading to a significant psychological impact over the caregivers along with the physiological effect on the neonates [4].

Furthermore, in certain study comparing term and preterm neonate response to acoustic challenge, scientists elicited that preterm unlike full-term neonates could not habituate to the stimuli even after repetitive

Table 2 Average heart rates and respiratory rates in different newborn care subunits

Inpatient unit	Average at 10 AM		Average heart rate at 5 PM		Average heart rate at 11 PM	
	Heart rate	Resp. rate	Heart rate	Resp. rate	Heart rate	Resp. rate
Level 2 ($N=16$)	154 (+3.37)	44 (+1.91)	146 (+4.15)	42 (+1.46)	144 (+2.90)	44 (+2.15)
Level 3 ($N=14$)	148 (+4.90)	47 (+2.23)	144 (+4.37)	44 (+1.68)	145 (+3.95)	42 (+2.22)
KMC ($N=10$)	124 (+5.29)	40 (+1.80)	130 (+4.25)	41 (+1.56)	123 (+5.21)	40 (+1.86)

Table 3 Comparison of the current study with previous studies

Reference	Sample size	GA/BW	Age at testing	Noise exposure	Results	*p*-value
Cardoso et al. [7]	61	Low birth weight neonates	Term, preterm	Ambient noise	An increase in HR A decrease in O2 saturation	< 0.05
Steinschneider et al. [8]	9	Term	2 +/− 5 days	100 dB	Increase in HR	-
Wharrad and Davis et al. [9]	42	Preterm: 32 weeks (mean) Full term	Full term: 5 days Preterm: 20-day mean	0, 80, 90, or 100 dBA for 5 s	Heart rate increased in all infants	< 0.01
Vranekovic et al. [10]	45	Preterm: < 1750 g Full term	Full term: 43–86 h Preterm: 26.6 days mean	100 dB warbled tone for 5 s	Initial increase and then decrease in all infants Less change in HR in preterm infants	< 0.05
Field et al. [11]	36	Preterm: 31–36 weeks Full term	Full term: 2–3 days Preterm: 23-day mean	90-dB rattle or buzzer for 2.5 s	Increased in all infants	< 0.01
Long et al. [12]	2	34–35 weeks	7 days	70–15 dBA sudden loud NICU noise	Increased with all stimuli	NA
Zahr and Balian [13]	55	23–37 weeks	48 h–21 days	Nursing interventions, NICU alarms	Increased with noise and nursing interventions	> 0.05
Current study	40	32–40 weeks	1–30 days	Ambient noise Average intensity: 65 dB Peak intensity: 74 dB	Increase in HR and RR	< 0.05

exposures [6]. In the following table (Table 3), we compare the results of the present study with that of previous studies.

Evaluating the studies included in the above Table 3, we can see that sudden transient noise stimuli initiate a startle response with waking up of the neonate which is more of a protective reflex; however, prolonged exposure to noise has led to stable persistent changes in heart rate and breathing pattern as corroborated in the present study with simultaneous measurement of ambient noise intensities and heart rate and respiratory rates of the newborns [7, 11, 12].

The physiologic responses to auditory stress events such as fluctuations in heart rate, intracranial tension, and respiratory rates may have a considerable impact on the preterm neonate's future neurological development as a result of changes in perfusion and oxygenation of the neural tissues [14].

Newborns have a better sleep cycle in quiet environment as in special room designated for kangaroo mother care, while there are instances of sudden waking up during transient high intensity noise in NICU. Noise-induced hearing loss is a well-established entity, but in neonates, it is not well quantified and needs a long-term audiological evaluation. Stressful noise stimuli at the NICU lead to increased risk for attention deficit, disordered speech-language acquisition, and hearing disorders, often attributed to the immature auditory system's exposure to technology-driven machinery and alarm noises in the NICU and lack of exposure to human speech [15].

It is therefore recommended to create a noise-free environment in the NICU which may lead to optimum development of the most fragile neonatal physiological system. Reduction in number of stressors and noisy equipment and proper maintenance of technical hardware shall help the infant to cope early to the physiological changes and help in early graduation from the NICU [16].

Conclusions

Sound level in tertiary care SCNU falls in the level of noise pollution attributed to equipment and gadgets with their alarms. Noise pollution causes immediate increase in heart rate and respiratory and altered sleep pattern in the babies. Early shifting of stable babies to KMC unit and step-down nursery prevents from prolonged exposure to high-level noise pollution. All NICU graduates should have assessment of hearing and long-term follow-up. Controlling noise pollution within NICU is of paramount importance, since numerous adverse effects can harm the infant physiological stability and future neurodevelopment. Social and psychological realm of health worker needs urgent improvement.

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Authors' contributions
SD and PC did the data collection and clinical work. RB was the supervisor; PC did data analysis and manuscript proofreading. The authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Ethics approval was taken from Institutional ethics committee, Silchar Medical College, India.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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