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Review paper

Noise in neonatal intensive care unit: effects on hospitalized preterm infants

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Abstract

For continued existence and survival, preterm infants depend on the Neonatal Intensive Care Unit (NICU). The NICU is a sophisticated and technology-driven environment, and preterm infants experience enormous stress in an NICU environment. Even though NICU is actually required by preterm infants for their continued existence, it may end up being an inappropriate milieu. The presence of overwhelming stimuli, most potent being the continuous presence of noise, may have various effects on preterm infants. Regardless of the recommendations by various committees, investigators have found that noise levels in the NICUs have exceeded the recommendations. The objective of this review was to find evidence regarding noise and its effects on hospitalized preterm infants. Studies reported provide evidence of the existence of noise in the NICU and its iatrogenic effects on preterm infants. But, the isolated nature of the studies limits generalizations. Most of the studies or reviews preclude any definite conclusions due to the relative uncertainty of data. Paucity of data on various iatrogenic effects of noise on preterm infants, suggests directions for further research establishing guidelines for best practices in NICU environment.

Keywords: Preterm infants, noise, sound, NICU

INTRODUCTION

Preterm birth not only affects preterm infants and their families, but also the healthcare services of the country, compelling preterm infants, to spend prolonged periods in the Neonatal Intensive Care Unit (NICU), losing opportunity to continue their normal growth and development which otherwise would have occurred, had they continued in the protective intra-uterine environment. According to Taquino and Lockridge (1999), the extra-uterine NICU environment has helped improve the rates of survival of preterm infants, who would have otherwise died.

The NICU is a sophisticated and technology-driven environment, and preterm infants experience enormous stress in the environment. The untimely birth predisposes a preterm infant to experience stress from the moment of birth, i.e., from the time of separation from the secure environment of the uterus. Preterm infants have immature body systems as observed by Blackburn (1995), especially the Central Nervous System (CNS) and so the transition to extra uterine life is complex, paving way for several postnatal morbidities and iatrogenic complications.

In an editorial pertaining to the organization of neonatal care in India, Nangia (2009), confesses that the quiet nursery concept founded by Julius Hess as well as Evelyn Lundeen, and propagated by Florence Nightingale, the founder of modern nursing with components of warmth, rest, quiet, and the like, had undergone drastic change to today's high-tech nurseries with ventilators, infusion pumps, multi-parameter monitors, and other gadgets surrounding

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a tiny baby. NICU that is required by the preterm infants for their continued existence and which actually helps them to survive, may end up being an inappropriate milieu; given the presence of overwhelming stimuli, most potent among them being the continuous presence of noise, caused by the sophisticated machinery and gadgets that may adversely affect the physiological stability, recovery, growth as well as the development of the preterm infants.

Perlman (2001) suggests that developmental problems and their persistence may be associated with the NICU environment. In line with this, Symington and Pinelli (2006) in a Cochrane systematic review, also opine that NICU graduates may bear the negative consequences of noise in NICU, which may be evident later in their life.

Recommendations for permissible noise levels in NICU environment

Noise is an undesirable sound as per American Academy of Paediatrics (AAP) Committee on Environmental Hazards (1974). The ambience of NICU should have sound or noise levels within safe limits for the healthy development of preterm infants. Krueger, Wall, Parker and Nealis (2005) define L_{eq} as "The average noise level over a period of time" andL_{10} as "A measure of decibel level exceeding for ten percent of the hour. Beranek (1988) define L_{max} as "The highest measured decibel levels which lasts for at least 1/20th of a second during the measurement period."

Environmental Protection Agency, Office of Noise Abatement and Control's Sound Study Group (1974), recommends, "Hourly equivalent sound levels (L_{eq}) of below 50 dBA in NICUs, second hourly L_{10} below 55 dBA and 1 second L_{max} of not more than 70 dBA". On the other hand, World Health Organization (WHO) (1999) recommends, "Daytime noise levels in patient treatment rooms should not exceed 35 dBA weighted". Philbin, Robertson and Hall (1999) in a review, recommend the permissible noise for nurseries meant to cater hospitalized neonates should be hourly L_{eq} of 50 dBA. The rationale provided by the authors for maintaining the hourly L_{eq} of 50 dBA is to preserve sleep.

The recent recommendations provided by the AAP Committee to establish recommended standards for Newborn ICU design (2007), is of opinion that in an NICU, an hourly L_{eq} should be 45 dB, whereas the L_{max} should be 65 dB and L_{10} should not exceed 50 dB.

Evidence of existence of noise in NICU environment

Besides the WHO (1999), various committees like the AAP Committee on Environmental Hazards (1974), Environmental Protection Agency, Office of Noise Abatement and Control (1974), AAP Committee on Environmental Health (1997) and Committee to establish recommended standards for Newborn ICU design (2007) have recognized the presence of noise in environment and have subsequently provided recommendations for permissible noise criteria. Investigators globally have repeatedly monitored the background noise in the ambience of the NICU. Regardless of the recommendations by various committees and researchers in collaboration, investigators have found that the noise levels in NICUs have exceeded the recommendations.

Philbin (2000), in a review, concluded that noise in the nursery rooms as well as incubator noise generally loud, chaotic, lacked pattern or rhythm. The author compared the results of eight studies that measured the sound and noise levels on an A-weighting scale. The sound and noise levels reported in these studies ranged from 38 dBA- 75 dBA. This retrospective study, points out that the lowest A-weighted sound level of 38 dB (A) was reported only from one nursery in Lund, Sweden, which was the only nursery that confirmed with the AAP recommendations for sound levels in NICU to be below 45 dBA, with transient levels not exceeding 65 dBA. Morris, Philbin and Bose (2000) in their review, also acknowledged that sound levels in NICUs range between 50-75 dBA. Earlier studies by Bess, Peek and Chapman (1979) as well by Long, Lucey and Philip (1980), observed that sound levels in the incubators and intensive care nursery ranged from 70 dB-117 dB. DePaul and Chambers (1995) also found that routine procedures done in NICU like placing bottles, closing incubator ports and running water during hand wash produced sound levels up to 75 dB.

It is obvious, that excessive sound, termed as noise, is possible even with simple routine procedures done in NICU. In yet another review Philbin (2004) stated that, "Sound, and its sibling vibration are difficult and sometimes costly to direct and confine". The author opined that the typical barrier to designing a quietly functioning NICU lies not in the technology, but in the social and psychological realm of the people working in NICU, and emphasized that, "Principles of planning a quiet NICU are simple, but the execution of a quiet NICU is not."

Abril et al., (2007) highlighted the mean sources of environmental noise in NICUs and the corresponding ranges from 68 dB -77 dB. The results of the study also showed that exterior background noise in NICUs was 57 dB (45dB - 67 dB) and the environmental noise due to cleaning was 89 dB (65 dB - 98 dB). The results establish the fact that the noise levels, exist in NICUs. Another weekly sound survey done by Williams, Drongelen and Lasky (2007) in two modern NICUs found that results were significant ($p<0.001$) for peak sound of above 90 dB in both the NICUs surveyed, with diurnal variation in sound levels i.e., an increase of 5 dB during the day.

Nathan (2007) measured noise levels of an NICU in Cape Metro-pole, South Africa and concluded that the noise levels in room one of the NICU on day one ranged from 63.5-66.7 dBA (L_{Aeq}), whereas the Sound Pressure Level (SPL) ranged from 62.0 to 66.0 dBA. On the second day, the noise levels ranged from 62.3-64.6 dBA (L_{Aeq}) and the SPL ranged from 61.0-64.0 dBA. The noise levels in the second room on the first day ranged from 64.2-65.2 dBA (L_{Aeq}), the SPL ranged from 63.0- 65.0 dBA, on the second day it ranged from 64.5-65.3 dBA (L_{Aeq}) and the SPL ranged from 61.9 - 64.8 dBA. Another study by Livera et al., (2008) reported measurement of noise in an NICU in South India. The study results demonstrated that the equipment and machines used in the NICU generated maximum noise levels. The mean levels and the range of noise measured in the NICU were: The ventilator room 69.99 dB (61.15 dB -72.48 dB), stable room 61.81 (57.22 dB – 66.02 dB), isolation room 56.95 dB (54.07dB - 58.77dB), extreme preterm room 54.56 dB (52.22dB -57.79 dB) and preterm room 57.12 dB (53.62 dB -59.52 dB).

Pinheiro et al., (2011) found noise in an NICU with highest mean L_{eq} of 80.4 dBA on the sixth day of the total measurement period of seven days. The authors also reported that L_{max} levels of 105.5 dBA was registered on the sixth day and L_{min} levels of 47.7dBA registered during the night shift of the first day, all of which exceeded the current recommendations. Ramesh et al., (2012) in a study measured the noise levels in an NICU in South India and found that range of sound levels in the NICU were: The ventilator room: 68.9 (67.1-70.8), in the isolation room: 61.2 (59.0-63.4) and in the preterm room: 56.6 (55.7-57.5). The levels reported show that, the existence of sound levels in all the rooms in NICU were more than the recommended levels.

Iatrogenic effects of noise on preterm infants hospitalized to the NICU

AAP Committee on Environmental Hazards (1974), in their review on the neonatal aspects of noise pollution, highlights that, excessive noise exposure produces deafness by damaging the organ of Corti. Deriving from results of several studies, the Committee cautioned about the use of ototoxic drugs like the salicylates, quinine, potent diuretics, antineoplastic drugs, and aminoglycoside antibiotics frequently administered to neonates can also affect neonates with impaired renal functions. In addition, effects of noise including auditory effects, a linear increase in Adrenocorticotrophic Hormone (ACTH), adverse cardiovascular responses, effects on speech/language development and sleep are highlighted. The Committee further cautioned the use of occlusive devices in neonates having unforeseen adverse effects like local reaction or sensory deprivation with delayed speech/language development.

In a cohort of 273 infants, weighing 1500g or less and who were exposed to noise of 65 dB, 10 had sensory neural hearing loss, out of which eight had bilateral hearing losses in speech frequencies (250-8000 Hz) among the 129 surviving infants. This 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. Even though, four were able to compensate for the loss with hearing aids and remedial help, two other children had unilateral losses, including one

with a loss of 70 dB at 8000 Hz. The study findings revealed no difference between length of stay and sensory neural hearing loss; however, analysis of variance with stepwise regression found that mechanical ventilation, duration of stay in an incubator significantly contributed to the hearing loss (Abramovich et al., 1979).

Long, Lucey and Philip (1980) assessed the impact of sudden loud NICU noise ranging from 70–75 dBA on two preterm infants of 34–35 weeks of gestational age. The source of this sudden loud noise was doors closing, diaper pails and staff conversation in the NICU whose ambient noise levels ranged between 60 - 65 dB during the measurement period. The authors reported that sudden loud noise resulted in physiological changes like decrease in oxygen saturation, increase in heart rate (HR), increase in respiratory rate (RR), increase in intracranial pressure, and sleep deprivation in the preterm infants. Lotas (1992) in a review asserted a vast difference between the environment of the uterus and the NICU environment. The authors reported that the ambience of NICU has potential to cause hearing loss, difficulty in processing auditory inputs, disrupts sleep and the physiological systems in infants. Subtle developmental problems occur in infants following significant exposure to the NICU's physical and care-giving environment.

Zahr and Balian (1995) compared the responses of 55 preterm infants aged 23 to 37 weeks gestation to noise and nursing interventions in NICU. Occurrences of loud noises common in NICU were studied in relation to the preterm infants' responses i.e., HR, RR, (HR) and Oxygen Saturation (SaO_2). A significant main effect of noise on SaO_2 was noted, $F(2, 34) = 8.44$, $p<0.01$ making it evident that noise resulted in clinically important changes in SaO_2 of preterm infants. The results showed significant difference ($p <0.01$) in oxygen saturation levels, that averaged 90% during noisy periods compared to 93% in quiet periods. From the findings of the study, the authors describe that noise was responsible for drop in SaO_2 in 14 %, rise in HR in 16%, as well as rise in RR in 13% of the infants. The study results also demonstrated that, noise was sufficient to cause a sympathetic response implicating noise as a noxious stimulus since 43% of the preterm infants exhibited fussing or crying to noise. Wharrad and Davis (1997) analyzed HR responses and respiratory responses of 42 infants (twenty preterm and twenty-two term infants) to white noise ranging from 80-100 dBA versus no stimulus for a duration of five seconds. The authors observed that at 90 and 100 dB (A) sound stimuli, there was increase in the HR ($p<0.01$) in the infants, implying that cardiovascular system was more responsive to auditory stimuli. The authors also reported that the RR decreased in response to acoustic stimuli, with changes significant in preterm infants.

Bremmer, Byers and Kiehl (2003) in a review also addressed that excessive auditory stimulation causes negative effects for the premature infants like negative physiological responses, such as increased HR/RR and decreased oxygen saturation. They hypothesized that most of the energy spent by preterm infants to mediate unwanted stressors in the NICU could be utilized by them primarily for their growth. Philbin and Gray (2004) proposed in a review that, "The traditional NICU includes an acoustic environment consisting of random and competing auditory signals that frequently challenge the immature, developing listener i.e., the preterm infant."The authors argued the unpredictable or chaotic acoustic environment of NICU may contribute to atypical attention abilities in children born preterm. A cohort study followed up Extremely Low Birth Weight (ELBW) infants (<1000 g) and found that these infants were exposed to noise ranging in the level of 50–60 dBA, when cared for in the incubators. The authors found that eleven among the thirty ELBW infants followed up, exhibited increased HR to noise (Williams, Sanderson, Lai, Selwyn, and Lasky 2009). Wachman and Lahav (2011) in a review suggested that loud transient NICU noise causes immediate physiological changes in the various systems of preterm infants. Additionally, the authors postulated that hearing loss very often occurs in preterm infants, who spend extended periods in the NICU, making them more vulnerable to high levels of noise.

CONCLUSION

It is evident from literature that, in spite of acknowledging that excessive noise in the NICU is an on-going problem, there is still a paucity of data on effects of noise on preterm infants, though many studies have documented the effects on full term infants. Studies discussed in this article provide evidence of the existence of noise in NICU. However, the isolated nature of the studies limits generalization. The literature incessantly provides a basis for prospective research, and raises concerns about the effect of ambient noise levels exceeding recommended levels in NICU environment.

Most of the studies, reported in literature preclude any definite conclusions due to relative uncertainty of data regarding effects of noise on preterm infants. These shortcomings of the studies limit implications for best practice for ambient sound/noise control in NICU for the benefit of preterm infants. Inconsistencies, evident from literature, suggest directions for further research in this area.

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