Reducing noise on the neonatal unit

There is increasing acceptance that noise on the neonatal unit can have detrimental effects for staff and for patients. In this article, we try to explain the physical properties of sound and extrapolate these into the clinical setting, including recommendations to minimise noise on the NICU.

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Keywords

noise; sound; decibels; preterm; newborn infant; developmental care

Key points

Ranganna R., Bustani P. Reducing noise on the neonatal unit. *Infant* 2011;7(1): 25-28.

1. Noise levels measured on neonatal units are unlikely to cause hearing loss in staff but can interfere with effective staff functioning.
2. Noise interferes with neonatal physiological stability and sleep patterns and is related to loudness and duration.
3. The insulating properties of the incubator mean that the most relevant sources of noise for infants are from alarms and CPAP circuits.
4. Staff training and alteration of behaviour are probably the most effective means to reduce unwanted noise on the NICU rather than expensive unit structural changes.

Over the past three decades, survival rates of preterm infants have progressively improved yet high rates of neurodevelopmental delay persist in survivors. This has prompted efforts to focus on improving long-term outcome[1].

Recently, there has been consideration that the intensive care environment may play a part in causing detriment to the neonate and this has been reflected by the increasing body of work supporting developmental care practices on the neonatal unit. These spectra of interventions and care packages aim to improve the stability of the neonate with the aim of improving long-term outcomes, based on the hypothesis that brain development can be adversely affected by the environment[2].

One particular focus of developmental care has been the effect of noise on the infant. Not only are there concerns about the potential damage to hearing that may be caused to preterm infants, but it is recognised that noise can influence short-term physiological stability of neonates and also the working practices of staff on the neonatal intensive care unit (NICU)[3,4]. Blind attempts to implement noise environmental standards will most likely be unsuccessful unless there is clear understanding of the properties of sound.

The physics of noise

Sound loudness as perceived by the human ear is difficult to measure hence sound pressure is used as a surrogate. This is expressed not in its pressure level (pascals) but as the logarithmic conversion of this value known as the decibel (dB). Decibels are a ratio of sound pressure rather than true levels and are related to the threshold of human hearing conveniently expressed as 0 decibels. **FIGURE 1** demonstrates that an increase in noise by 20dB is equivalent to a ten-fold increase in sound pressure. An increase in 6dB is equivalent to a doubling in sound[4].

As sound is a perceived noise, there exist different scales adapted to the range of frequencies considered relevant. For example a dog whistle may be very loud to a dog but imperceptible to the human ear, so how should it be measured? The decibel-A scale is weighted to those frequencies most perceived by humans, eg 3 kilohertz.

When adding sounds together the calculations can be confusing. If the two noises are within 1dB of each other, 3dB is added to the loudest sound to give the total. When the second sound is 4-9dB quieter, only 1dB is added to the loudest sound, while noises 10dB below the loudest noise can be disregarded. Thus if one alarm is 80dB and another is 75dB, the total sound is only 81dB. These examples demonstrate two things; that the loudest noise around is the one that effectively drowns out other noises, and that sound physics is an extremely complex subject beyond the scope of this article. Utilisation of audiologists when considering the measurement of noise on a neonatal unit is recommended!

Noise levels in neonatal units

Recommendations for noise levels in neonatal units have been proposed by the American Academy of Pediatrics and with the design of new nurseries it is hoped that these will be taken into account[5]. These suggest that average noise levels should be below 45dB in infant areas and that transient sounds should not exceed 65dB. A survey of neonatal units found only one that conformed to these standards with average noise levels at 38dB. The others surveyed demonstrated a range of mean noise from 48dB to 75dB. This represents a 64 fold difference in noise between the loudest and quietest units[6].

The possible effects of sound on healthcare providers have not been widely acknowledged. Occupational health standards state that workers should not spend more than eight hours at 90 dBA as this will lead to hearing damage[5]. These levels have never been demonstrated on a neonatal unit. However, noise interferes with staff concentration, interpersonal communication and performance. Where English is not one's first language, potential for miscommunication is likely to be greater with background noise[7].

Sound Pressure (µPa)	Sound pressure level, dB	Example
20	0	Threshold of hearing
200	20	Studio for sound pictures
2,000	40	Quiet office, audiometric booth
20,000	60	Conversational speech (3ft)
200,000	80	Very noisy restaurant
2,000,000	100	Looms in textile mill
20,000,000	120	Woodworking
200,000,000	140	Hydraulic press
2,000,000,000	160	Threshold of pain, jet plane
20,000,000,000	180	Rocket-launching pad

FIGURE 1 Sound pressure and SPL.

Fetal development

The human cochlea and peripheral sensory end organs complete their normal development by 24 weeks of gestation. Ultrasonographic observations of blink-startle responses to vibroacoustic stimulation are first elicited at 24 to 25 weeks of gestation. There are several studies, which have looked at fetal responses to sound levels when *in utero*. The main sounds experienced by the fetus are the conducted sounds from the mother, with the majority of external sounds being insulated[8]. Preterm delivery exposes the infant to sounds that would not have been experienced until term.

Physiological effects on noise on the infant

Preterm infants have decreased autonomic and self-regulatory abilities and are vulnerable to changes in their environment. Studies of both term and preterm infants suggest increases in noise transiently increase heart rate, however not all studies have showed consistent results. Responses are dependent on maturity (preterm infants are less able to habituate), prior noise exposure, and sleep-alert status. The nature of the sound can influence response with mid-level noises, eg 55-75dBa resulting in deceleration, while louder noises result in acceleration[3,4]. Blood pressure can also be acutely affected by noise as demonstrated by Jukovicova and Williams with potential hypertensive, hypotensive or biphasic responses in infants[9,10].

There are fewer studies, which have looked at the effect of noise on the respiratory system. These studies suggest oxygen saturations decrease and respiratory rate alters in infants when exposed to high noise levels[1-13].

Studies in healthy infants clearly demonstrate an effect of noise on sleep patterns. At 65dB, 20% of infants are woken up after 12 minutes of exposure. However, an increase in noise levels to 70dB causes a majority of babies to wake after only three minutes of noise[14]. These effects may be worse in preterm infants suggesting keeping noise significantly below these levels is important to attain restful sleep. Sleep disturbance can affect growth and feeding patterns of infants and there are decreased EEG response thresholds in term infants exposed to higher decibels of noise[15]. Sleep responses provide some of the strongest support for nursery noise recommendations.

Long-term effects of noise

Though there are well established studies looking at short-term effects of noise in infants, the long-term effect of exposure to noise is not well understood and has been poorly researched. It is estimated that neonates admitted to NICU are 10 times more likely to develop sensorineural or mixed hearing loss[16]. However a neonate is exposed to several other environmental factors other than exposure to noise which can affect hearing such as mechanical ventilation, aminoglycosides, asphyxia and elevated bilirubin levels. The research in this area is limited and there are no studies looking directly at the effects of NICU on hearing loss in preterm infants.

One small randomised study looked at cognitive benefits of using ear plugs for preterm infants. Use of plugs resulted in better weight gain on the unit with no evidence for complications to the ear. Long-term assessment of surviving high risk infants demonstrated improved cognitive outcomes and larger head circumferences, albeit in a small subset of the original group[17].

Tough on noise, tough on the causes of noise!

Determining how to approach noise reduction on a unit requires finding the sources of loud noise specific to your unit. Commercial dosimeters (noise measurers) are available that change colour to show staff that noise levels are too high[18] (**FIGURE 2**). These however appear to have only short-lived effects on changing staff behaviour and it is certainly our own experience that after a few weeks they are unnoticed. Some of these devices allow one to download and analyse noise levels and can prove useful in demonstrating compliance with AAP standards. We noted our own unit exceeded AAP recommended noise levels significantly, but were taken aback by noise levels being of a comparable level during day and night shifts, an observation noted by others[19].

Unless one is making audio recordings while collecting this data, it will not be possible to determine which are the sources for the noise. This is an exercise that some units have carried out and has proven an invaluable method for addressing a noise

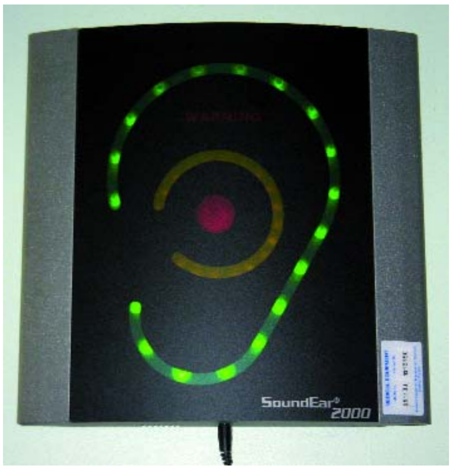

FIGURE 2 Commerical dosimeter with visual alert.

reduction strategy. Liaison with an audiology department is to be recommended for your own unit to carry out this exercise. However, in the absence of this facility, certain common sources of sound have been determined previously and measures to address these are feasible.

Noise sources in the NICU are numerous consisting of the equipment used to provide intensive care, care giving routines and behaviours of staff, which can be structurally predetermined by the layout, design, and specific functionality of the area, eg air-conditioning, door mechanisms, location of staff desks, travel paths[20].

Incubators

The main defence against noise for neonates has been regarded as being the incubator. It is shown that patients in incubators typically receive 5 to 18 dB less sound pollution than do children in open-bed warming units. However incubator design can vary and the sound of the incubator motor can reduce the benefits provided by the plastic walls[21]. Our own analysis of audio-recordings from within an incubator showed that incubators dampen low frequency sounds such as speech but high pitched noises were barely reduced. This gives a degree of reassurance that speech from staff is less likely to affect neonates; however alarms from equipment permeate freely into the incubator and probably constitute the main source of intermittent loud noise for the intensive care infant. Sounds generated within the incubator are unfortunately amplified for the occupant, reinforcing the need to avoid sources of noises within.

Alarms

Noise from alarms is difficult to reduce in terms of decibels, and a quiet alarm does not provide safety benefits. Certain actions however can reduce the significant ‘noise load’ that they provide. The simplest intervention is prompt silencing of alarms, and this practice should be encouraged before assessment of the problem. Alarms going off very frequently may discourage appropriate intervention due to staff habituation, hence parameters should be set that require action or investigation. For example, in our nursery saturation alarms were set to limits of 88-93% when breached for more than 10 seconds. We now have altered these to a breach of 30 seconds outside 83-94% suggesting assessment is required. A back-up alarm for a desaturation below 80% for 10 seconds is employed and most commercial monitoring systems provide this facility of ‘red’ and ‘amber’ alarm settings.

Respiratory support

Ventilators and CPAP are important sources of noise in NICU. We have noted the Sensormedics oscillator more than doubles noise levels in our nursery, but what is not obvious to staff is how this noise is perceived to the infant in the incubator. The low frequency sound from these machines is dampened down by incubators while the sound from the flow of gas to the patient dissipates within the thoracic cavity via the endotracheal tube. Noise inside the incubator has been recorded as 54dB. This is higher than aimed for but far lower than the 65-70dB we have recorded outside the incubator with this equipment in use[22].

The major source of low frequency noise in the incubator that the infant can hear is from CPAP. Here, the high flow of air emerges into the postnasal space and through the expiratory limb into the incubator. Although Surenthiran and Karam measured noise in the postnasal space in babies on CPAP and showed that the noise generated was in excess of 85dB, there is unpredictable dampening of this postnasal space noise before it reaches the ears[23,24]. Notwithstanding this, noise levels in an incubator with use of CPAP are approximately 64dB, many times louder than when nursed in an open incubator (55dB) demonstrating the amplifying effect of the incubator. It is important to leave the expiratory limb hanging out of the incubator or use an expiratory exhaust to reduce noise.

It is well established that noise generated by CPAP is dependent on the flow rate such that an increase of flow from 5 to 8L/min can increase noise by two to three-fold[24]. Hence, rather than increasing flow rates to generate pressure where there is a poor seal, it is better to address the poor fit of the nasal prongs. Seal providing devices (eg Cannulaide) that sit between the prongs and the nares have been designed to do this and allow much lower flow rates. It is noted that manufacturers (eg SLE, UK) are targeting this issue and are starting to produce CPAP generators (at the patient end) which have lower noise generation.

Noise protection

Potential measures to reduce the noise experienced by neonates in incubators are ear protectors. Ear muffs target a higher frequency sound range than ear plugs and can reduce noise by 6dB thus halving noise exposure. There are to date limited long-term studies with these; however ear muffs have been shown to improve oxygen saturations and sleep patterns over a short period[25]. As previously mentioned, ear plugs have been studied in a limited group of infants, but have been shown to reduce noise levels by 17dB[17]. We would at least consider these options for short noisy procedures such as MRI in the absence of further data.

Staff and the environment

The unit design can play a key role in reducing some of the noise generated in NICU. Some nurseries have progressed to single cot rooms, with distant alarm monitoring at the nursing desk rather than cotside, allowing noise and activity to be minimised. Formal planning guidelines and minimal standards for the design of newborn intensive care units are available which aim to optimise design within the constraints of available resources[26]. Stevens demonstrated a newly designed nursery had 6dB lower noise levels than a comparative unit when unoccupied[27]. These recommendations may reduce the noise level in NICU but they require lot of time developing and funding. A lower cost approach which may provide greater dividends is concentrating on changing the knowledge and behaviour of the members who constitute the NICU environment.

Educational programmes increase the awareness among the staff about the negative impact of high noise level in NICU. These can be made more effective by displaying noise graphs from within the local nursery and playing audio recordings from within the neonatal incubator, particularly when CPAP is in use and alarms are sounding. Both Robertson and Byers emphasised the synergistic benefits of addressing staff behaviours (most significantly conversation) and ambient environmental noise (eg heating and air-conditioning, sound absorption flooring and ceiling panels), however noise levels were still higher than recommended standards[22,28].

Noise levels in NICU can be at their highest during ward rounds and in places of common gathering. Some simple steps, such as having discussions outside the patient areas and turning down phone ringer volumes, can reduce noise. Discussion noise is particularly important once infants are in open cots. Implementation of quiet hour has been shown to reduce crying times and increase sleep time during these periods[29], but must raise the question – why isn't every hour a quiet hour?

Summary

The culture of high technology and aggressive pharmacological interventions that exist in neonatology can distract practitioners from the basic tenets of care. It would be unlikely that any adult would function effectively after a weekend spent in an intensive care room trying to get restful sleep, so why should we not try to provide the same rest for our patients that we ensure for ourselves? Noise is excessive on neonatal units and effective measures already exist to minimise it and its effects. All neonatal units should audit their sound levels and aim to improve on these for the benefits of staff and babies.

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