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Work-Related Noise Exposure in a Neonatal Intensive Care Unit

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ABSTRACT

Premature infants are exposed to continuous noise in neonatal intensive care units (NICUs), which impairs sleep behavior and leads to growth and developmental delays. The study measures the intensity of noise exposure in a German NICU and determines diurnal rhythmic variations. For this purpose, sound levels are measured for 22 work shifts in a patient room and an incubator and the mean daily noise exposure levels (LEX,8h) of the early, late and night shifts are calculated and the peak sound level (LpCpeak) is recorded. To test for a day-night rhythm, these are compared using one-factor ANOVA. The measurement results in LEX,8h and LpCpeak values of up to 49.7 dB(A) and 124.4 dB(C), respectively, in the incubator and 55.4 dB(A) and 110.3 dB(C), respectively, in the patient room. The most noise-intensive work activities included suctioning patients and the conversations conducted during this process, with an LAeq of 63 dB(A). In addition, numerous, impulsive noise events were identified that contribute to noise exposure of preterm infants, some of which is very high. A day-night rhythm of noise exposure could not be demonstrated. The results of the presented study prove that noise exposure is too high whereby with high probability the sleep behavior of the premature infants is impaired.

Keywords: Neonatal intensive care unit (NICU), Noise, Day-night rhythm, Incubator, Sound level

INTRODUCTION

Preterm infants are children born before the 37th gestation week. After birth, they often have to be cared for in neonatal intensive care units (NICUs), where they are continuously exposed to noise (Boggini et al. 2020). Premature infants are in a particularly vulnerable exposure group, as noise impairs sleep patterns and leads to growth and developmental delays (Williams et al. 2009). Noise can also have detrimental effects on the cardiovascular and respiratory systems (Boggini et al. 2020, Romeu et al. 2016, Schefer Cardoso et al. 2015, Wachmann & Lahav 2011) and lead to psychological distress in preterm infants, manifested, for example, in delayed language development (Marik et al. 2012, McMahon et al. 2012, Stromswold & Sheffield 2004). Because of these extensive health effects of noise, the American Academy of Pediatrics (1997) recommends that continuous sound levels should not exceed 45 dB(A) in NICUs. However, noise measurements in NICUs show that this level is often not met. Darcy et al. (2008), Krueger et al. (2005), Parra et al. (2017), and Lasky and Williams (2009) measured sound levels averaging 54 to 68 dB(A). Only a study by Domanico et al. (2011) measured an equivalent continuous sound level (Leq) of 33 dB(A) in a single room after remodeling a NICU.

A limitation of the previous studies is that the noise measurements were not carried out for an entire work shift. This makes it impossible to make statements about the diurnal rhythm of noise exposure, which can have an influence on the circadian rhythm of premature infants, for example. Since noise affects the sleep behavior of preterm infants (Kuhn et al. 2013) and a disturbed sleep-wake cycle has effects on thermoregulation, the immune system, and hormone production (Schultes & Fehm 2004), an insufficient day-night rhythm can impair the developmental process (Schrader & Schrader 2001). In addition, noise affects heart rate (Long et al. 1980, Vranekovic et al. 1975), blood pressure (Jurkovicová & Aghová 1989, Williams et al. 2009), oxygen saturation (Johnson 2001, Zahr & Balian 1995), and respiratory rate (Wharrad & Davis 1997) of preterm infants. However, the intensity and direction of these effects are not homogenous in previous studies, which is due to the fact that mostly the physiological response to high noise stimuli of 80 to 100 dB(A) has been studied (Field et al. 1979, Jurkovicová & Aghová 1989, Vranekovic et al. 1974, Wharrad & Davis 1997). Studies on natural noise exposure in NICUs and its effect on preterm infants are not sufficiently available so far (Wachman & Lahav 2011).

The present work aims to determine the intensity and diurnal rhythm differences of noise exposure in a German NICU.

METHOD

To record the noise exposure, the sound levels are measured for 22 work shifts in the patient room of a German perinatal center (level 1). The selected patient room has four treatment places, all of which are occupied at the time of the measurement. One premature baby is in an incubator and is being ventilated non-invasively (CPAP ventilation). Three premature babies are being cared for in warming or crib beds. The measurements are performed according to ISO 9612 (2009). Two class 1 sound level meters according to IEC 61672-1 (2014) from NTi Audio (Liechtenstein) are used (sound level meter: XL2; microphone: MA2230; sound calibrator: CAL200). The A-weighted equivalent continuous sound level (LAeq) is recorded as a time average of the sound level over the measurement time and the C-weighted peak sound level (LpCpeak), each with a sampling frequency of 10 Hz. The measuring instrument is calibrated before and after each measurement. The measurements are performed simultaneously with two identical sound level meters in the incubator and in the patient room. In order not to interfere with the workflow in the patient room, one microphone is fixed to a wall (height 160 cm). The second microphone is covered with a hygienic protective cover for ultrasound probes (20 × 200 mm, Dahlhausen company), attached to the outer wall of the incubator with a suction cup stand and positioned with the microphone tip near the head of the premature baby (distance approx. 20 cm).

To evaluate the measurements, the daily noise exposure levels (LEX,8h) are calculated from the LAeq. They correspond to the average sound level of an eight-hour work shift and allow direct comparison and further processing of the results. The arithmetic mean and standard deviation (aM ± SD) of LEX,8h are determined for the early, late, and night shifts, and an independent-samples t-test ($\alpha = .05$) is used to test whether the incubator and patient room LEX,8h differ. If there is a significant difference, Cohen's effect size d is determined. A one-sample t-test ($\alpha = .05$) checks for compliance with the American Academy of Pediatrics (1997) recommendations. To test for a day-night rhythm of noise exposure, the association between the averaged LEX,8h of the early, late, and night shifts in the patient room and incubator, respectively, is determined using one-sample ANOVA ($\alpha = .05$). All statistical data analyses were performed using SPSS Statistics 24 software (IBM Corp., USA).

RESULTS

The sound levels of 8 early, 7 late and 7 night shifts were recorded with a total measurement time of 176 hours. Table 1 shows the calculated LEX,8h (aM ± SD) and LpCpeak (aM ± SD) in the patient room and incubator. The highest measured LpCpeak was 124.4 dB(C) in the incubator and 110.3 dB(C) in the patient room.

The recorded sound levels were normally distributed (Shapiro-Wilk tests, $p > .05$). The one-sample t-tests performed demonstrate a highly significant difference between the recorded LEX,8h in the patient room and the recommended guideline value of 45 dB(A) ($t = 23.628$, $p < .001$, $n = 24$, $aM = 54.3$, $SD = 1.9$). The same is true for LEX,8h in the incubator ($t = 7.583$, $p < .001$, $n = 24$, $aM = 48.8$, $SD = 2.4$).

The performed single factorial ANOVA confirms that the averaged LEX,8h values in the patient room do not differ significantly between work shifts ($F(2, 21) = 2.821$, $p = .082$, partial $\eta 2 = .212$, $n = 24$). The same is true for the averaged LEX,8h values in the incubator ($F(2, 21) = 1.373$, $p = .275$, partial $\eta 2 = .116$, $n = 24$). Thus, a day-night rhythm of noise exposure could not be detected in the studied NICU.

The LEX,8h averaged over all work shifts was 54.3 ± 1.9 dB(A) for the patient room and 49.5 ± 2.4 dB(A) for the incubator. The independent

Table 1. Result of sound level measurement of 22 working shifts of a NICU.

Sound level	Work shift	n	Incubator*	Patient room*
$L_{EX,8h}$ [dB(A)]	early	8	49.7 ± 2.8	55.4 ± 2.0
	late	7	47.8 ± 2.2	53.9 ± 1.6
	night	7	48.7 ± 1.9	53.3 ± 1.6
L_{pCpeak} [dB(C)]	early	8	113.6 ± 7.7	104.2 ± 3.8
	late	7	107.6 ± 4.4	104.1 ± 4.1
	night	7	107.4 ± 9.2	101.6 ± 1.6

*aM ± SD

samples t-test performed shows that the averaged LEX,8h is significantly higher in the patient room (aM = 54.3, SD = 1.9, n = 24) than in the incubator (aM = 49.5, SD = 2.4, n = 24), $t(46) = -8.156$, $p < 0.001$. The Cohen's effect size is $d = .77$, corresponding to a strong effect.

CONCLUSION

The results of the sound level measurements show that all measured LEX,8h exceed the recommendation of the American Academy of Pediatrics (1997), by at least 3 dB(A). Premature infants are exposed to excessive noise levels in both the incubator and patient room (e.g., warming bed or crib). In the full-shift measurements the results of previous studies are thus confirmed, in which - with shorter measurement times - the recommended sound level of 45 dB(A) was also exceeded (cf. Darcy et al. 2008, Krueger et al. 2005, Lasky & Williams 2009, Parra et al. 2017). A common cause of noise is conversations that occur between employees (Baker 1992, Connor & Ortiz 2009, Gabor et al. 2003, Morrison et al. 2003, Overman et al. 2008). When these occur during noisy work activities, such as suctioning of preterm infants, they tend to be conducted at a slightly higher pitch and louder. This phenomenon, known as the Lombard effect (Klatte et al. 2010), leads to a self-amplification of the noise exposure. To avoid this, conversations should be avoided as far as possible in NICUs during noise-intensive work activities. Another cause of noise are alarms from medical devices, which were also identified in previous studies by Carvalho et al. (2005), Morrison et al. (2003) and Gabor et al. (2003). Because of the high number of false alarms, nurses find them particularly disturbing (Lawless 1994). A simple possibility for prevention would be the use of radio message receivers (pagers), which would only transmit optical, instead of optical-acoustic device alarms, to the staff, which would further reduce the noise in the patient room (cf. Imhoff et al. 2009). As expected, LEX,8h are lower in the incubator than in the patient room. The difference is on average about 6 dB(A). Striking are the high LpCpeak values in the incubator, which with the highest measured peak sound level of 124.4 dB(C) are already close to the pain threshold for adults and are not reasonable for premature infants. The measured high LpCpeak values are caused by placing work equipment on the incubator while feeding or caring for the premature infants. The incubator can act as a resonance body and amplify the sound impulse introduced. To reduce these high peak sound levels, the placing of work equipment on the incubator must be avoided as a matter of urgency. In order to achieve this, there must be sufficient storage space within the nurse's reach. If this is not the case, it should be provided immediately to prevent noise exposure. This problem should also be given special consideration in the development of new incubators. For example, the shape of the incubator's housing dome could prevent work equipment from being placed on it (e.g., by means of a curved surface). An alternative would be to provide a storage facility on the incubator that is acoustically decoupled from the incubator door. The evaluation of the sound level measurement shows that there is no significant difference between the LEX,8h of the early, late and night shifts. Thus, a day-night rhythm of noise exposure does not exist either in the patient room or in the incubator. It can be assumed that the sleep behavior of premature infants is disturbed by the permanently high noise exposure (Kuhn et al. 2013). To improve sleep quality, rest periods should be introduced in the NICU (Bhutta & Anand 2002), during which lighting levels and nursing activities are also reduced for a certain period of time (Dennis et al. 2010).

Limitations of the presented study include the fact that the sound level measurements and work analyses were only conducted in a German NICU. However, the transferability of the results of the measured LEX,8h values could be proven on the basis of the available literature. Since corresponding publications for LpCpeak values are not available, the transferability of these results should be investigated in further studies. A technical limitation results from the use of the hygienic protective covers for ultrasound probes, which were pulled over the microphone in the incubator. This leads to an attenuation of the sound wave hitting the microphone membrane which results in a reduction in the measured sound pressure levels in the incubator. The validity of the measured values in the incubator is thus limited, since higher measured values can be expected without the protective covers. However, since the available data already exceed the recommended guideline values of the American Academy of Pediatrics (1997), they do not contradict the results of the study.

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