NOISE EXPOSURE CAUSED BY ARTIFICIAL VENTILATION IN THE NEONATAL INTENSIVE CARE UNIT

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1. INTRODUCTION

Children who graduate from the neonatal intensive care unit (NICU) are at 10-15 times greater risk for sensorineural hearing loss than other children (Doyle & Casalaz, 2001; Veen, et al, 1993).The possible causes of this increased risk for hearing loss are multiple: these children are born with predisposing medical conditions, are treated with potentially ototoxic medications, and live in a noisy environment while in the NICU that may contribute to noise-induced hearing loss (NIHL).

Noise levels measured in the NICU range from 54 – 87 dBA (Levy, Woolston & Browne, 2003) with ambient room L_{eq} of 55.8 dBA (Robertson, Cooper & Vos, 1999). Incubator levels of 60-65 dBA have been reported (Long, Lucey & Philip, 1980).

While the effects of noise exposure on the hearing of adults are well described, the susceptibility of neonates to NIHL is not. The developing ear may be more sensitive than the adult ear to noise damage. For example, Douek et al (1976) demonstrated loss of outer hair cells in newborn guinea pigs when subjected to incubator noise, but no damage to the cochlea of adult guinea pigs subjected to the same noise.

In humans, cochlear cell differentiation begins at 9-10 weeks gestational age (Glass, 1999). The cochlea begins to function around 20 weeks when it may become susceptible to noise damage (Hayes & Northern, 1996). In animal models, noise overstimulation had the greatest negative effect during period of rapid growth and neuronal differentiation which occurs between 28 – 40 weeks (Glass, 1999). It is very likely, therefore, that preterm infants are particularly susceptible to NIHL.

In addition to the hearing risk, noise exposure causes physiological effects in the premature infant that include increases to heart rate, blood pressure, and respiratory rate, and decreased oxygen saturation (Bremmer, Byers, & Kiehl, 2003). As a result, recommendations for NICU sound level limits have been developed. Nzama, Nolte and Dorfling (1995) recommended that levels inside incubators should be are below 60 dB. The U.S. EPA limits average daytime levels to 45 dB and average nighttime levels to 35 dB (American Academy of Pediatrics Committee on Environmental Health, 1997). The *Consensus Committee to Establish Recommended Standards for the NICU Design* recommends a maximum hourly L_{eq} of 50 dBA and an impulse maximum of 75 dBA (Bremmer, et al, 2003).

Neonates in the ICU who are being artificially ventilated are exposed to addition sound from the ventilation equipment. For example, Surenthiran et al. (2003) measured noise levels in the ear canal and nasopharynx of infants and reported alarmingly high levels of over 100 dB SPL in the nasopharynx with continuous positive airway pressure (CPAP). Other ventilation options are also available in the NICU. With little knowledge of the relative noise exposures produced by alternative ventilators and the effect on infant's hearing, further research is needed to evaluate the potential harm of such exposures.

2. Purpose

The goals of our research are to (1) determine the noise levels and the spectra of the noises produced by five different modes of artificial ventilation and by spontaneously breathing neonates in the NICU, (2) compute the noise exposure for each type of artificial ventilation, and (3) determine the possible risk of noise-induced hearing loss for ventilated neonates. Preliminary noise measurements for neonates in the NICU are presented here.

3. Methods

3.1 Participants

Sound measures were obtained with 21 medically stable neonates at 24.4 - 41.0 weeks gestational age. The neonates weighed between 490 and 3935g at the time of the recordings. Consent of the parent(s) or guardian was received prior to participation.

Neonates were spontaneously breathing, spontaneously breathing with low flow oxygen, or artificially ventilated. Five artificial ventilation systems were in use: conventional ventilation, Vapotherm 2000i, CPAP, high frequency jet, and high frequency oscillation ventilation.

3.2 Procedures

Dosimetric measures. The microphone of a Larson Davis Spark 703+ dosimeter was placed inside the incubator at a location approximately 15 cm above the infant's head (standard position). Noise levels were measured over a 24-hour period

Probe tube measures. ER-7 probe tube microphones and a two-channel recording system (SpectraPlus software) were used to record one-minute samples of the incubator sound. For each sample, one probe tip was located at the standard position and the other in the ear canal or nasopharynx.

A minimum of five one-minute recordings were made for each of the artificial ventilators and four recordings were made with the spontaneously breathing infants. The sound recordings were then analyzed in 1/3-octave bands and A-weighted to obtain overall A-weighted, peak frequency band, and level in the band.

4. Results and Discussion

Table 1 displays two samples of the sound level measurements obtained in the incubators of the spontaneously breathing and ventilated neonates. The 24-hour A-weighted L_{eq} values ranged from a low of 53.7 dB with a conventional ventilator to a high of 66.2 dB in the incubator of spontaneously breathing neonate. The range of levels was greatest for spontaneously breathing neonates.

Table 1: Examples of dosimetric measures in occupied incubators

Ventilation Mode	L_{eq} (dBA)	L_{max} (dBA)	L_{min} (dBA)
Conventional	53.7	89.3	50.4
Conventional	55.9	84.9	52.1
CPAP	64.7	90.8	46.2
CPAP	65.3	91.9	56.6
High freq. jet	60.3	94.5	54.4
High freq. jet	59.8	93.1	49.4
High freq. osc.	56.4	82.6	53.5
High freq. osc.	57.2	92.4	48.9
Spontaneous	61.1	100.0	37.1
Spontaneous	66.2	100.6	42.0
Vapotherm	53.9	87.6	50.4
Vapotherm	60.7	96.8	49.8

Table 2 displays the levels measured in the ear canals of the neonates in the different ventilation conditions. Again, the lowest levels were observed in the conventional ventilation condition. Ear canal levels exceeding 70 dBA were found with several of the ventilators. The 1/3-octave band containing the highest level is also listed in Table 2. Peak frequencies varied considerably both from one ventilation condition to another and within condition. Sound levels in the nasopharynx followed a similar pattern, with some of the levels in spontaneously breathing neonates being higher than those using artificial ventilation.

Data collected in this study will be used to compute the transfer function from the standard microphone location to the ear canal and the nasopharynx. The relative intensity of ear canal sound levels produced by the different artificial ventilators and the individual differences between neonates using the same type of ventilation will be examined.

Table 2: Example of overall sound levels measured in the ear canal during artificial ventilation and 1/3-octave peak frequency and band levels

Ventilation Mode	Overall level (dBA)	Peak Freq. (Hz)	Peak band Level (dBA)
Conventional	40.9	3150	37.4
Conventional	59.4	4000	53.0
CPAP	73.3	6300	67.5
CPAP	70.3	6300	67.5
High freq. Jet	65.0	2500	55.9
High freq. Jet	73.7	800	67.8
High freq. osc.	58.2	315	51.9
High freq. osc.	58.5	5000	50.1
Spontaneous	54.9	125	48.0
Spontaneous	55.8	125	45.7
Vapotherm	70.8	1000	66.6
Vapotherm	70.2	10000	63.6

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