Results of an Acoustic Incubator Cover among Preterm Infants: Incubators and Modes of Respiratory Therapy

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Abstract

We previously described high frequency (HF) sound spectra (SSA) within unoccupied incubators using acoustic foam in an incubator cover. This acoustical product incubator cover was made from Sonexwet Baffles™ a melamine foam designed to absorb sound in frequencies above 500 Hz with a noise reduction coefficient of 0.95.

The current two-group study describes HF sound within occupied incubators of 33 premature infants (M = 28 weeks G.A.) using the Acoustic Incubator Cover© (AIC). Each subject received seven HF noise assessments. Every subject was on one of three respiratory therapy modes. Sound spectra were analyzed by a Larson Davis SLM 824 with SSA functions. A total of 230 hours of sound spectral analysis were recorded. RM-ANCOVA with mixed models was used to analyze the linearly transformed data. Results indicated that HF sound was reduced at 1000, 2000, 4000, and 8000 Hz (p < 0.001) in the treatment group when compared to the control group. The AIC was most effective in HF sound reduction by Incubator model covariate at 1000 Hz (F = 11.37, p = 0.0023). The AIC was most effective in HF sound reduction by respiratory mode covariate at 8000 Hz (F = 22.57, p < 0.0001). Nasal cannula mode of respiratory therapy produced the most intense HF sounds. Based on these findings we recommend that SSA be part of Level III NICU noise assessments.
1. INTRODUCTION

Ambient neonatal intensive care unit (NICU) noise continues to exceed American Academy of Pediatrics (AAP) guidelines\(^1\)-\(^8\). Incubators provide some attenuation in SPL from ambient noise depending on model and proximity of operating respiratory support modes\(^9\)-\(^15\).

We have previously reported ambient noise levels across sound frequencies in a tertiary multi-bed open NICU\(^16\). We next reported Sound frequencies in an unoccupied incubator under control and treatment conditions\(^17\). The purpose of this article is to describe a pilot study using the treatment among hospitalized premature infants in the same level III NICU.

2. THEORETICAL FRAMEWORK

2.1. Conceptual Model for studying Atypical Sound Reduction

Intrauterine sound environment is quite different from the sound environment of a tertiary, multi-bed neonatal intensive care unit (NICU). Noise transmitted into incubators includes intense, high frequency sounds (≥ 500 Hertz) from life support systems, staff activity and respiratory therapy\(^9\),\(^13\),\(^18\). In utero, a fetus of comparable gestational age receives sound by bone conduction in frequencies attenuated by uterine structure\(^19\). In an NICU, premature infants receive airborne sound in frequencies ≥500 hertz (Hz) without attenuation\(^20\). Intense environmental noise retards auditory cortex development\(^21\). Sound frequency influences the development of the auditory system, specifically neuronal connection of the hair cells to spiral ganglion and cochlear nuclei\(^22\). Clearly sound environments of an intensive care nursery must be made more compatible for pre-

2.2. Hospital Noise Pollution

Margaret Topf developed a middle-range theory of hospital noise pollution, Enhancement of Person-Environment Compatibility (EPEC)\(^23\)-\(^24\). Person-environment compatibility is an environment that meets the needs of the occupants\(^24\). According to Topf, nursing interventions\(^25\) in an NICU should adapt the environment to meet the needs of preterm infants. Identification of noise intensity is the first step in reduction of the environmental stressor of noise\(^24\). Noise measurement assesses the “fit” between the patient and the environment. For this study, noise measured in time-weighted average decibels (LEQ) on an A weighted scale and Hz assessed the fit between the person (i.e., preterm infant) and the micro-environment of the incubator.

2.1.1. Enhancing Premature infant-Environment Compatibility

To make the incubator more like the intra-uterine environment is to make the incubator more compatible with the needs of preterm infants. Sound-absorbing material has some of the insulation effects of the intra-uterine environment. Sonexwet Baffles™, for example, were designed to absorb sound in frequencies above 500 Hz. The two-inch thick, melamine foam incubator cover has a noise reduction coefficient of 0.95. Covering an incubator with this sound-absorbing material reduces noise that penetrates its plexiglass walls.

3. STUDY DESIGN AND METHODS

3.1. Design

This longitudinal two-group, repeated
measures experimental study examined the effectiveness of the treatment condition in reducing high frequency sound in occupied incubators. Effectiveness of the treatment condition required performing Sound Spectral Analysis (SSA) for 1 hour each day of the week for duration of the neonate’s care within an incubator.

3.2. Sample

The study protocol was approved by the study site’s Institutional Review Board. The sample consisted of 33 preterm infants with birth weight less than 1800 grams. Inclusion criteria were: preterm infants requiring at least two weeks in an incubator, medically stable and informed consent obtained. The enrolled subjects were randomly assigned per computer generated list to treatment or control group and one of four time measurement hours (7 – 11AM).

3.2.1. Ethnicity and Gender

Of the 33 subject, 21 were African-American, 10 were Caucasian, and two were Hispanic-American. Among African-American subjects, two-thirds were female. Among Caucasian subjects, half were female. Of the two Hispanic-American subjects, one was female.

3.2.2. Gestational age and birthweight

Gestational age of the sample population ranged from 23 weeks to 36 weeks ($M = 28$ weeks, S.D. = 2.5 weeks). Differences in gestational age between the two groups were not significant ($p = 0.12$). Birth weight ranged from 490 grams to 1690 grams ($M = 1000$ grams, S.D. =292 grams). Differences in birthweight between the two groups were not statistically significant ($p = 0.67$).

3.2.3. Mean birth weight by assigned group

Mean birth weight in the treatment group was 1026 grams (S.D. = 241.4 grams) compared to the control group mean birth weight of 981.9 grams (S.D. = 339.8 grams). The difference in mean birth weight was not statistically significant ($t = -0.43, p = 0.66$).

3.2.4. Apgar scores

One-minute Apgar scores for the sample ranged from 1 to 8. Five- minute Apgar scores ranged from 3 to 9. Half of the subjects required Apgar assessment beyond 5 minutes.

3.3. Materials

3.3.1. Acoustical Incubator Covers®

Enhancing Person Environment Compatibility was operationalized in this study by covering occupied incubators with sound-absorbing material. The treatment incubator cover was made from a 2-inch thick Sonexwet Baffle™ measuring 2 X 4 feet. Sonexwet Baffles™ are made of Willtec®, an open-cell melamine foam covered by Tedlar film. The foam panels were form-fitted to each of the three models of incubators in use at the study site. The treatment cover fit over the top, back and side panels of the subject’s incubator.

3.3.2. Noise Measurement equipment.

Effectiveness of the EPEC intervention was determined by comparing differences on the time-weighted average decibels (LEQ) across 500-8000 Hz in incubators between a treatment and control group.

The noise measurement equipment con-
sisted of the Larson Davis Sound Level 824 Meter with SSA function, microphone with extension cable (EXA010), calibrator (CAL 200), external power source and computer interface (CBL006). The principal author, previously by Larson Davis\textsuperscript{16}, operated the noise measurement equipment. The 824 SLM was calibrated before each measurement with 114 dB tone.

3.4. Method

3.4.1. Placement of the Sound Level Meter Microphone

The principal investigator secured the microphone of the sound level meter to the interior wall of the incubator with tape approved for use on plexiglass. There was no contact between the equipment and the infant. A sterile glove was placed over the microphone except for its tip. The microphone was then placed 4 cm above the incubator mattress near the baby’s head, via side tubing portlets at the head of the incubator bed. If respiratory tubing occluded HOB portlets, the foot of the incubator portlets was used. Following noise measurement, the microphone and cable were cleaned with Coverage™ spray.

3.5. Data Analysis

All statistical analyses were performed using SAS 9.1.3. Effect size was based on results of two studies\textsuperscript{17,19}. To detect a 3 dB reduction (large effect), with power of .80, alpha of .05, required a sample size minimum of 16 subjects per group (N = 32) each with seven SSA measurements (224). To allow for subject attrition, 21 subjects per group (n = 21) were enrolled (total N = 42). Five subjects were transferred. Three developed MRSA and were dropped from the study. The ninth subject expired before group allocation.

Descriptive statistics were calculated on all data. Variables potentially influencing noise levels within incubators, including incubator model and mode of respiratory therapy, were considered as covariates in mixed models.

3.5.1. Statistical Analyses

Repeated measures analysis of covariance (ANCOVA) with mixed models was used to examine differences between the treatment and control groups in noise levels at central frequencies and the time-weighted average decibels (LEQ). Each subject had 7 repeated measures which were considered as replicates, and an unstructured covariance structure was assumed between the repeated measures. Decibel data were linearly transformed. The denominator degree of freedom was adjusted using the Kenward-Roger method.

4. RESULTS:

There were 230 one-hour noise measurements made among three models (Drager Air Shields, C2000 Ohmeda, and the ACCESS Ohmeda) of 33 subjects. LEQ between the two conditions was compared resulting in a 0.6 dBs difference which was not statistically significant. Frequencies between the treatment and control were analyzed. The treatment condition was statistically lower than control condition at 1000, 2000, 4000 and 8000 Hz (p <0.001).

Table 1 shows the ANCOVA models for noise at central frequencies. Adjusted least square means are presented in their linearly transformed values. Covariate mode of respiratory therapy had the greatest im-
Impact on noise levels in occupied incubators at HF ≥ 1000 Hz. Treatment group was statistically significant at 1000 (p = < 0.01) and 2000 Hz (p = < 0.05).

**Table 1.** ANCOVA models across 500 to 8000 Hz.

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Figure 1. Bar chart dBA across frequencies comparing ambient sound to incubator sound profiles.

**Ambient vs. Incubator Sound Spectra**

**Frequencies 500 to 8000 hertz**

**Two Incubator conditions: Treatment vs. Control**

All decibel data were linear transformed before analysis.

Figure 1 shows differences across selected frequencies during ambient, control and treatment conditions. XXX\(^6\) had previously described sound spectral analysis in an open, tertiary level NICU. Ambient sound profile was similar to other reported NICU profiles\(^4,6,11\). Control group incubators reduced HF sound exposure from the ambient environment particularly well at 4000 and 8000 Hz. The treatment intervention reduced HF sound exposure from the ambient environment 10 to 14 dB across frequencies. Treatment intervention did not reduce HF sound as well in the *in vivo* as the *in vitro* study likely to exclusion of respiratory modes in the *in vitro* study.
Figure 2. Bar chart CPAP, Linearly transformed values.

Figure 2 shows differences across selected frequencies in the CPAP mode between the treatment and control group. Control group sound pressure levels ranged from 51.8 dB at 500 Hz to 44.9 dB at 8000 Hz. Without attenuation by sound absorbing material, CPAP produced as much HF sound as the ambient environment. The sound absorbing treatment reduced HF sound by 3 dB from 500 to 2000 Hz; by 4.5 in 4000; and by 6.8 at dB 8000 Hz.

These findings support the observation that CPAP contributes to HF sound energy in neonatal intensive care units.31
Figure 3. Bar chart Nasal Cannula, linearly transformed values

Figure 3 indicates differences in mean linearly transformed decibels

Figure 3 indicates differences in mean linearly transformed decibels across selected frequencies with the nasal cannula mode of respiratory therapy between the treatment and control group. The treatment reduced HF sound at 1000 Hz by 3.4 dB, at 2000 Hz by 4.3 dB, at 4000 Hz by 6.8 dB and at 8000 Hz by 6.4 dB.

5. DISCUSSION

In the United States, 50,000 to 75,000 preterm infants require neonatal intensive care\(^2^6\). During the weeks to months of hospitalization, preterm infants are exposed to extra uterine HF noise likely to impede normal auditory system development\(^2^7\). Much of this atypical sound exposure transmits through incubators from modes of respiratory therapy.

5.1. Atypical sound exposure from modes of respiratory therapy

Of the numerous respiratory therapy modes used in NICUs, the current study examined sound profiles of the Infant Star conventional ventilator, the Aladdin System for CPAP and low flow nasal cannula. The next paragraphs compare results of the current study to earlier frequency descrip-
ations of respiratory therapy modes.

5.1.1. Ventilators vs. CPAP

Previous studies supported the need to evaluate differences among modes of respiratory therapy. Surenthiran et al measured sound frequencies outside and within the ears of neonates receiving one of three respiratory therapy modes. Mean noise intensity (dB SPL) during Infant Flow Driver CPAP ranged around 50 dB from 500 to 8000 Hz (Hz) outside the neonate’s ear and post-nasal space. Within-ear/post-nasal space measurements were up to 50% (3.2 dB) more intense than outside-ear measurements. Mean noise intensity during SLE 2000 ventilator treatment ranged from 33.7 dB at 2000 Hz to 46.6 dB at 500 Hz outside the neonate’s ear. Within-ear/post nasal space measurements during conventional ventilation were slightly higher than external measurements.

During CPAP, the current study found lower intensities (dB) across frequencies than Surenthiran. During conventional ventilator treatment, the current study found higher intensities across frequencies than Surenthiran.

5.1.2. Nasal cannula

The low flow nasal cannula mode of respiratory therapy produced the most intense high frequency sounds. Control conditions indicated 42.3 dBA at 4000 Hz and 40.4 dBA at 8000 Hz. Roberts et al reported 38.2 and 41.3 dBA at the same frequencies. Treatment conditions were lower by 2.3 and 6.4 dBA, respectively.

5.2. Acoustic foam use in NICUs

5.2.1. Neonatal incubators

This is the first longitudinal study to examine the effect of using acoustic foam to reduce HF sound in occupied incubators. Johnson used acoustic foam squares inside occupied incubators which reduced time-weighted average (LEQ) noise levels by 3.2 decibels. Although in this study there was no statistically significant difference between the experimental and control groups on the variable of LEQ, there were statistically significant differences between the treatment and the control at 1000 and 2000 Hz. Altuncu et al measured equipment and impact noises inside isolettes with and without sound-absorbing panels. Sound absorbing panels significantly reduced transient sound pressure levels ($p < 0001$). Long term use of acoustic foam inside incubators may not conform to infection control standards.

5.2.2. Interior structures

Walsh-Sukys used Silent Wall Panel with noise reduction coefficient of 0.75 on 33% of wall surfaces in a tertiary NICU. Use of sound absorbing material was part of a light and sound reduction modification study. Thus, the statistically significant ($p < 0.001$) reduction in LEQ cannot be attributed only to the sound absorbing material.

5.3. Limitations of the current study

The current study was an in vivo test of an in vitro intervention. Thirty-three enrolled infants were hospitalized for an average of 70 days. Each infant experienced varying lengths of respiratory therapy. Three different incubator models were used for neonatal care. Each of the three models
had sound frequency spectrums that varied considerably between them.

Therefore, it is difficult to assess the treatment efficacy with statistical precision. Manufacturers strive to adapt incubator models to produce and receive less toxic noise. Sound profiles change as a result of improvements. Zacarias et al examined three recent best performing incubator models: Ohmeda Omnibed Giraffe (Giraffe), Ohmeda Ohio Care Plus Access 3000 (OCP3000), and Ohmeda Ohio Care Plus Access 4000 (OCP4000). Of the three, the OCP3000 was the best insulated resulting in the most attenuation of HF ambient sound. The OCP3000 performed better than any of the three models in the current study. Thus, generalization of the current study findings is limited to neonatal intensive care units that use older incubators.

6. SUMMARY

This was the first longitudinal study to use a product that absorbs high frequency sound as an incubator cover for preterm infants. The purpose of this pilot study was to compare the differences in sound frequencies in incubators between two groups, one of which received a noise reduction intervention, Acoustical Incubator Covers®. The control group had usual blanket incubator covers. The main outcome variable was noise measured in frequency (Hz) and intensity (decibel) between the two groups. Covariates of respiratory therapy mode and incubator model explicated HF sound reduction. Treatment compared to control condition reduced HF sound at 1000 and 2000 Hz. By respiratory therapy mode, the treatment condition appeared to be more effective than the control in reducing HF sound among the Drager Air Shields and Ohmeda isolettes.

The current study supports a need for sound spectral analysis in occupied incubators. Variability found between respiratory therapy modes indicates that ventilators, CPAP and nasal cannula contribute to HF sound exposure among hospitalized preterm infants. Neonatal intensive care unit sound measuring protocols should add frequency analysis to sound pressure level assessment.

References


