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ARTICLE

Noise and Light Exposures for Extremely Low Birth Weight Newborns During Their Stay in the Neonatal Intensive Care Unit

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What's Known on This Subject

Noise and light levels in NICUs can exceed AAP recommendations and could have permanent adverse effects on growth and development.

What This Study Adds

Previous studies measured NICU room acoustics. This study measured the sound and light environments of newborns for the duration of their stays in the NICU. We also characterized the important factors that affected noise and light levels.

ABSTRACT

OBJECTIVES. The objectives of this study were to characterize noise and light levels for extremely low birth weight newborns throughout their stay in the NICU, evaluate factors influencing noise and light levels, and determine whether exposures meet recommendations from the American Academy of Pediatrics.

METHODS. Sound and light were measured inside the beds of extremely low birth weight newborns ($n = 22$) from birth to discharge. Measurements were recorded for 20 consecutive hours weekly from birth until 36 weeks' postmenstrual age, biweekly until 40 weeks, and every 4 weeks thereafter. Clinical variables including bed type and method of respiratory support were recorded at each session.

RESULTS. Age-related changes in respiratory support and bed type explained the weekly increase of 0.22 dB in sound level and 3.67 lux in light level. Old incubators were the noisiest bed types, and new incubators were the quietest. Light levels were significantly higher in open beds than in incubators. The variations in noise and light levels over time were greatest for open beds. Noise and light levels were much less affected by respiratory support in incubators compared with open beds. A typical extremely low birth weight neonate was exposed to noise levels averaging 56.44 dB(A) and light levels averaging 70.56 lux during their stay from 26 to 42 weeks' postmenstrual age in the NICU. Noise levels were rarely within American Academy of Pediatrics recommendations (5.51% of the time), whereas light levels almost always met recommendations (99.37% of the time).

CONCLUSIONS. Bed type and respiratory support explained differences in noise and light levels that extremely low birth weight newborns experience during their hospital stay. Noise levels exceeded recommendations, although evidence supporting those recommendations is lacking. Well-designed intervention studies are needed to determine the effects of noise reduction on the development of extremely low birth weight newborns. *Pediatrics* 2009;123:540–546

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Key Words
noise, light, neonatal intensive care unit, extremely low birth weight, newborns

Abbreviations
AAP—American Association of Pediatrics
ELBW—extremely low birth weight
CPAP—continuous positive airway pressure
Leq—equivalent continuous noise level
PMA—postmenstrual age
IDR—interdecile range
GLMM—generalized linear mixed models
CI—confidence interval
ROP—retinopathy of prematurity
IQR—interquartile range

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THE PHYSICAL ENVIRONMENTS of hospitals are critical to good patient care. The American Academy of Pediatrics (AAP) warns that high noise levels in NICUs may adversely affect newborn growth and development.[1] High light levels (eg, phototherapy) and the lack of regular light/dark cycles may also adversely affect newborn patients.[2] The AAP recommends noise levels <45 dB(A)[3] and light levels <646 lux (60 foot-candles)[4] in NICUs.

Previous studies have measured noise and light levels in rooms and incubators in the NICU. [5–17] However, to our knowledge, there have been no published surveys characterizing noise and light exposures of patients in the NICU for the duration of their hospitalizations. In this study, noise and light exposures of newborns <1000 g birth weight (extremely low birth weight; ELBW) were measured from birth until hospital discharge. ELBW newborns are among the sickest and most immature newborns; they tend to stay the longest in the NICU.

The objectives of this study were to (1) describe the noise and light environments of ELBW newborns for the duration of their stay in NICUs, (2) identify variables responsible for variability in those environments, and (3) evaluate noise and light levels in the NICU in accordance with AAP recommendations.

METHODOLOGY

Subjects

ELBW newborns ($n = 30$) were enrolled within 7 days of birth after admission to Children's Memorial Hermann NICU in Houston, Texas, and after parental consent was obtained. The noise and light environments of these newborns (presented in this article), as well as the relationship between noise and light levels and clinical events, will be evaluated. This study was reviewed and approved by the institutional review board for the University of Texas Health Science Center at Houston. The newborns were studied between October 2005 and April 2007.

NICU Environment

The study NICU was a 104-bed unit in a large, private hospital. The NICU was constructed in 1999, with a high priority on noise abatement. The unit was divided into 12 large rooms (8 patients per room) and 8 isolation rooms. The floors were carpeted, the drawers and trash bins were plastic, and staff work areas were separate from patient care areas. Each room had 3 windows that allowed natural light into the patient areas. There were no other formal procedures to manage noise or light levels, although incubators were routinely covered with blankets. Incubators were covered with blankets to reduce light and sound exposure.

ELBW newborns in the study NICU were frequently cared for in Giraffe Omnibed incubators (Ohmeda Medical, Laurel, MD). Older model incubators, the Ohio Care Plus Access MOD 4000 Incubator and the Ohio IC Incubator (Ohmeda Medical, Columbia, MD), were also used. Infants requiring care in open warmers were placed in Ohio Infant Warmers (Ohmeda Medical, Columbia, MD). Before discharge, newborns were cared for in open cribs (Cribettes, HARD, Buffalo, NY).

The most commonly used mechanical ventilator in the study NICU was the Babylog 8000 Plus (Dräger Medical AG and Co, Lübeck, Germany). It also provided continuous positive airway pressure (CPAP). Mechanical ventilation was provided by an Avea Ventilator (VIASYS Respiratory Care, Inc, Palm Springs, CA) in a few instances. VIASYS SensorMedics Model 3100A Oscillatory Ventilators (VIASYS Respiratory Care, Inc) were used for high-frequency oscillatory ventilation. Disposa-hoods (Utah Medical Products, Inc, Midvale, UT) were used in 12 sessions.

Procedures

Larson Davis Spark 703+ Personal Noise Dosimeter (Larson Davis, Provo, UT) microphones were secured inside the bed of each study newborn within 30 cm of the newborn's ear. Equivalent sound level (Leq) in A-weighted dB was recorded at 1-second intervals. TES 1336A light meter (RS232/Datalogger [TES Electrical Electronic Corp, Taipei, Taiwan]) sensors were also placed inside the bed, within 20 cm of each newborn's head. Light measurements were recorded in lux (lm/m^2) at 6-second intervals.

Newborn gestational ages were calculated from the obstetrician's estimated date of confinement based on last menstrual period, ultrasound, and obstetric examination and extracted from the mother's medical chart. Postmenstrual age (PMA) at each testing session was calculated from the gestational age. Sound and light measurements were recorded for at least 20 consecutive hours each week until the newborn reached 36 weeks' PMA. After 36 weeks' PMA, the recordings were collected every 2 weeks until 40 weeks' PMA, and every 4 weeks thereafter. The final recording session was completed for each newborn during the week before hospital discharge. We reasoned that less frequent sampling would adequately characterize sound and light levels as newborns aged and care stabilized.

Analyses

Noise and light levels measured at 1 and 6-second intervals, respectively, during the weekly recording sessions were quantified by equivalent sound pressure levels (Leq) and mean light levels (in lux). Noise and light levels were further quantified by the 10th, 30th, 50th, 70th, and 90th percentile noise levels in dB (L10–L90) and light levels in lux (lux10–lux90). Variability in noise and light levels was measured by the interdecile (10th to 90th percentile) range (IDR) for noise and the SD for light. In addition, the percentages of sound and light measurements that exceeded AAP recommendations[3,4] were measured.

Generalized linear mixed models (GLMMs) were calculated separately for the 16 dependent variables measuring noise and light levels described earlier. Because sound was measured on a log scale (dBA), it was necessary to transform those measurements to sound pressure in Pascals (Pa) to analyze them. [17–19] Statistics calculated on sound measurements recorded in dB without transforming them are misleading. For example, the mean sound pressure level of a group of measurements in dB is not the arithmetic mean of those measurements. Instead, the dB measurements must be converted to sound pressure, a linear scale, before averaging. After analyzing the data in Pa, the results were transformed to dB(A) for presentation.

Restricted maximum likelihood was used to estimate model parameters because restricted maximum likelihood variance estimates are less biased than maximum likelihood variance estimates for small sample sizes. The Newton-Raphson maximization algorithm was used to find the restricted maximum likelihood solutions.

The fixed or predictive component for all of the GLMMs calculated included PMA, type of bed (old incubators, Giraffe Omnibeds, or open beds [including cribs and radiant warmers, which did not differ regarding noise and light levels after considering other factors], and respiratory support (none [room air], nasal cannula, CPAP, or mechanical ventilation). Mechanical ventilation included 3 recordings of high frequency ventilation, which were similar to conventional ventilation in noise and light levels. The type of bed by respiratory support interaction was evaluated to determine whether bed type affected the noise and light levels associated with method of respiratory support. In addition, independent variables listed in Tables 1 and 2 were evaluated in

TABLE 1 **Patient Characteristics**

Patient Characteristics	
Subjects, *N*	22
Male, *n* (%)	7 (31.9)
Race, *n* (%)	
Black/African American	12 (54.6)
White/Caucasian	5 (22.7)
Hispanic	4 (18.2)
Asian	1 (4.6)
Birth weight, mean (SD), g	764 (139)
Gestational age, mean (SD), wk	27 (2)
Apgar score at 5 min, median (IQR)	7 (6–8)
Respiratory distress syndrome requiring surfactant, *n* (%)	20 (90.9)
Days on ventilator, median (IQR)	11 (2–70)
Intraventricular hemorrhage, grade III or higher, *n* (%)	4 (18.2)
Length of stay, mean (SD), d	107 (39)
Failed NICU discharge hearing screen, *n* (%)[a]	3 (15.0)
ROP, *n* (%)	13 (59.1)
ROP requiring laser surgery, *n* (%)	5 (22.7)
Survival to discharge, *n* (%)[b]	22 (78.6)

[a] Two of 22 surviving newborns were transferred to other hospitals and were not screened for hearing. Two failed their hearing screen unilaterally but were assessed after discharge to have no sensorineural hearing loss. One newborn failed the hearing screen bilaterally and did not return for a follow-up audiological evaluation.

[b] Of the 28 newborns remaining enrolled in the study.

TABLE 2 **Session Characteristics**

Session Characteristics	
Sessions[a]	210
Level of care, *n* (%)	
Isolation	2 (1.0)
Level II	78 (37.1)
Level III	130 (61.9)
No. of newborns in room, median (IQR)	7 (7–8)
Bed type, *n* (%)	
Overhead warmer/surgical bed	10 (4.8)
Giraffe Omnibed incubator	91 (43.3)
Older incubator	67 (31.9)
Open bed/open Crib	42 (20.0)
Source of oxygen, *n* (%)	
Mechanical ventilator	69 (32.9)
CPAP	34 (16.2)
Nasal cannula or hood	66 (31.4)
Room air	41 (19.5)
O_2 desaturations $<$80% per d, median (IQR)	17 (6–34)
Bradycardias $<$100 beats per min per d, median (IQR)	3 (1–8)
Sessions with episodes of apnea $>$20 s, *n* (%)	32 (16.5)

[a] Includes only sessions with both light and sound data.

separate models for their effects on noise and light levels by including them with PMA, type of bed, and respiratory support.

Only those predictor variables (eg, type of bed, respiratory support, etc) whose association with the outcomes was unlikely to be explained by chance ($P < .05$) will be discussed. A Bonferroni adjustment was used to evaluate all pairwise fixed effect contrasts (at PMA = 32.7 weeks, the average age when the measurements were made). To communicate more directly differences in sound and light levels associated with the predictors, we presented the model predicted sound and light levels for significant predictors (bed type and method of respiratory support combinations) rather than the fixed component coefficients, the random component variances, their SEs, and the associated statistics.

The weekly measurements were clustered within individual newborns (a 2-level hierarchical model) to account for the correlations among measurements. PMA at assessment was analyzed as a random variable in the calculated GLMMs. Four correlation structures accounting for the correlation among random effect parameters (the G matrix) were evaluated (identity, independent, exchangeable, and unstructured). The correlation structure for the error matrix (the R matrix) was the identity (diagonal) matrix. The identity correlation structure evaluated random intercept models; the other 3 structures evaluated random coefficient (random intercepts and slopes) models. Specifically, we evaluated individual newborn differences in sound and light levels (random intercepts), as well as individual newborn differences in changes in noise and light levels over time (random slopes). The Bayesian Information Criterion was used to evaluate model fit. The results were similar regardless of the correlation structure. Because model fit was similar across correlation structures as were the fixed model parameter estimates and because all models assuming an identity correlation structure (random intercept models) converged to a solution, model results assuming an identify correlation structure will be presented in this article.

Diagnostics were performed to ensure that assumptions were met and outliers did not influence the results. Analyses were performed using Stata (Intercooled Stata 10.0 [Stata Corp, College Station, TX]) and NCSS 2007 (NCSS, Kaysville, UT).

RESULTS

Sample Characteristics

After reconsidering their participation in the study, the parents of twins withdrew their newborns from the study before completing the first recording session. Of the 28 remaining newborns enrolled, 22 survived to be discharged from the hospital (see Table 1). The 6 newborns who died differed significantly by a Wilcoxon Rank-sum test from the survivors in gestational age at birth (23.8; SD: 0.6 vs 26.7 weeks; SD: 1.9 weeks for the survivors), birth weight (552; SD: 83 vs 764 g; SD: 139 g for the survivors) grade III or IV intraventricular hemorrhage (66.7% vs 18.2% for the survivors), and length of stay (31; SD: 18 vs 107 days; SD: 39 days for the survivors). Newborns who died did not differ from the survivors on other variables listed in Table 1. After accounting for bed type and method of respiratory support in a generalized linear mixed model, the noise levels (Leq) and light levels (in mean lux) of newborns who died did not significantly differ from those who survived.

Table 2 characterizes session characteristics for survivors with both noise and light recordings. Over 60% of the sessions were in level III rooms, with typically 7 newborns in a room. The study newborns received supplemental O_2 for $>$80% of the recorded sessions. Oxy-

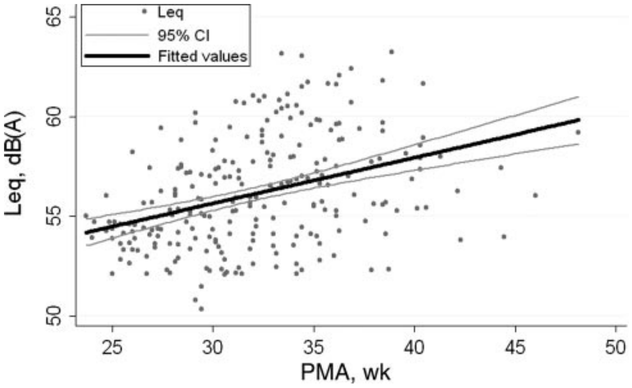

FIGURE 1
Equivalent sound levels (Leq) for each recording according to PMA.

gen desaturations of <80% were common during a 24-hour recording, as were bradycardias of <100 beats per minute. Apnea events lasting >20 seconds were recorded in 16% of the sessions.

Noise Levels

We expected that noise levels would decrease with age as newborns matured, became healthier, and required less intensive care. Rather, noise levels increased (see Fig 1) by 0.22 dB per week (95% confidence interval [CI]: 0.13–0.30). The expected noise exposure for a typical ELBW newborn during their stay in the NICU can be determined from the regression equation (Leq: 56.34 + 0.22 [centered PMA in weeks]).

The paradoxical result of increasing noise levels with age is explained by the type of bed and method of respiratory support. Figure 2 presents predictions from a GLMM evaluating the independent contributions of bed type and method of respiratory support to the Leq. Bed type ($F_{2,208.5} = 40.75$; $P < .001$), method of respiratory support ($F_{3,242.1} = 7.50$; $P < .001$), and their interaction ($F_{6,207.4} = 4.00$; $P < .001$) were significantly associated with Leq. After adjusting for bed type and method of respiratory support, the association between age and Leq was no longer significant ($F_{1,236.6} = 0.13$; $P = .715$). Other predictors (demographic and clinical variables; see Table 1) were not associated with Leq after adjusting for age, bed type, and method of respiratory support. The increase in noise level with age was explained by age-related changes in bed type and respiratory support.

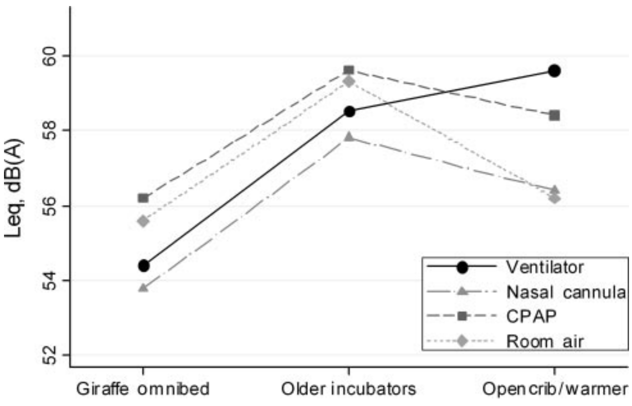

FIGURE 2
Sound levels for all study participants according to bed type and respiratory support predicted by a GLMM, including PMA, bed type, and respiratory support and their interaction as predictors.

Old incubators were the noisiest bed types, and the Giraffe Omnibeds were the quietest. Differences in noise levels in those beds were less affected by respiratory support than in open beds (ie, the bed type by respiratory support interaction was significant, ($F_{6,207.4} = 4.00$; $P < .001$). Noise levels in open beds were significantly higher for mechanically ventilated newborns than newborns on nasal cannula/hood or room air with newborns on CPAP intermediate. In incubators, CPAP was the noisiest method of respiratory support.

When it was relatively quiet in the NICU (L90, the lowest decile of noise levels), newborns in older incubators experienced noise levels ~8 dB more intense than newborns in Giraffe incubators ($F_{1,207.9} = 216.13$; $P < .001$) or open beds ($F_{1,206.1} = 144.92$; $P < .001$). The effect of respiratory support depended on bed type (ie, the bed type by respiratory support interaction was significant, $F_{6,204.6} = 3.16$; $P = .006$). In open beds, ventilators and CPAP were significantly noisier than nasal cannula/hood or room air (~5 dB noisier). In contrast, noise levels associated with the method of respiratory support did not significantly differ for newborns in incubators. At the noisiest times in the NICU (L10, the highest decile of noise levels), the differences in noise levels among the bed types were reduced although those differences were significant ($F_{2,205.0} = 19.22$; $P < .001$). The Giraffe incubators were quieter than the other 2 bed types averaged over all methods of respiratory support. The disparities in noise levels in the open beds between mechanical ventilation or CPAP and nasal cannula/hood or room air were considerably reduced in magnitude at the noisiest times but still significant ($F_{6,204.5} = 3.16$; $P = .006$). Differences in noise levels intermediate (L70, L50, and L30) to the quietest and noisiest times were intermediate to the differences recorded at those extremes.

With 1 exception, none of the noise levels measured (L90, L70, L50, L30, and L10) differed as a function of age or other independent variables measured after adjusting for bed type and method of respiratory support. The 1 exception was retinopathy of prematurity (ROP). Newborns with ROP experienced higher noise levels than newborns without ROP ($P < .05$ for L90 [$F_{1,23.5} = 4.67$], L30 [$F_{1,1358.2} = 4.19$], and L10 [$F_{1,2324.5} = 4.16$] with similar nonsignificant trends at other noise levels). The ROP effects were independent of the bed type and respiratory support effects.

We calculated IDRs of the Leqs to characterize the variability in noise levels (see Fig 3). Bed type was significantly associated with the Leq IDRs over time ($F_{2,169.5} = 136.3$; $P < .001$). Noise variability was greatest for open beds (mean IDR:12.8 dB [95% CI: 12.2–13.4]). In the Giraffe incubator, the mean IDR was 9.0 dB (95% CI: 8.3–9.7); it was only 3.7 dB (95% CI: 2.4–4.8) in the older incubators.

The effect of the method of respiratory support on the

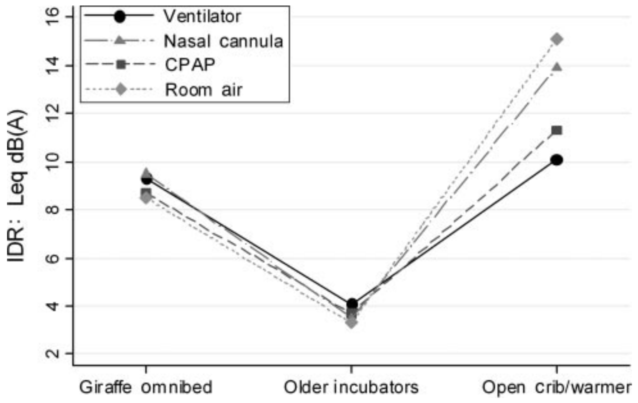

FIGURE 3
Expected IDRs for sound measurements (within each recording) according to bed type and respiratory support predicted by a GLMM, including PMA, bed type, and respiratory support and their interaction as predictors.

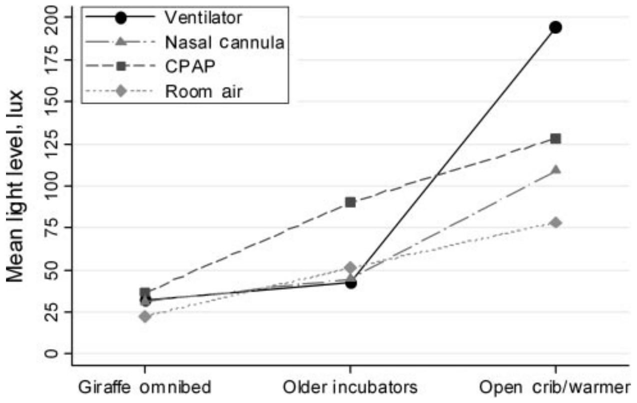

FIGURE 4
Expected mean light levels according to bed type and respiratory support predicted by a GLMM, including PMA, bed type, and respiratory support and their interaction as predictors.

variability of noise levels differed by bed type ($F_{3,119.1}$ = 7.01; $P < .001$). In open beds, noise levels associated with nasal cannula/hood (mean: 13.9 dB [95% CI: 13.1–14.6]) and room air (mean: 15.1 dB [95% CI: 14.4–15.8]) were significantly more variable than the noise levels associated with ventilation (mean: 10.1 dB [95% CI: 8.6–11.4]) and CPAP (mean: 11.3 dB [95% CI: 9.4–12.8]). In incubators, noise variability was reduced and did not differ significantly depending on the method of respiratory support.

AAP-recommended 45 dB(A) sound levels were achieved only by newborns in open beds breathing room air or on a nasal cannula/hood. The AAP-recommended sound levels were achieved a median of 35.7% (interquartile range [IQR]: 20.7%–40.7%) and 21.0% (IQR: 0.0%–34.0%) of the time, respectively, by newborns in those circumstances. For newborns in all other circumstances, the AAP-recommended sound levels were almost never achieved (median: 0.00% [95% CI: 0.00%–0.00%], for all other circumstances except newborns in the Giraffe incubator on a nasal cannula/hood, median: 0.00% [95% CI: 0.00%–0.70%]).

Having sampled sound and light levels longitudinally, we were able to predict average exposures for the duration of the typical ELBW survivor's stay (26–42 weeks' PMA) in the NICU from calculated regression equations. The Leq for the typical ELBW newborn during their NICU stay was 56.44 dB, the L90 was 49.20 dB, the L10 was 57.93 dB, and the percentage of time within the AAP-recommended sound level was 5.51%.

Light Levels

Phototherapy to reduce elevated bilirubin levels greatly affected the recorded light levels. For the 251 light sessions from the 22 newborns that survived to discharge, 11 (4.38%) were recorded while phototherapy was administered. Median light levels during phototherapy recordings (median light levels: 809 lux [IQR: 704–1399 lux]) were ~20 times as intense as nonphototherapy recording sessions (median light levels: 40 lux [IQR: 22–76 lux]). Eye patches shielded the eyes of the newborns receiving phototherapy. Because light exposure was atypical during those recording sessions, the 11 phototherapy sessions were excluded from the data set analyzed.

Mean light levels increased with PMA of the newborn 3.67 lux per week (95% CI: 1.55–5.78 lux). The regression equation relating age and light levels was mean lux = 61.96 + 3.67 (centered PMA in weeks). The only other variables measured that were associated with light levels were the bed type, the method of respiratory support, and their interaction. After adjusting light levels for type of bed and the method of respiratory support, age was no longer significantly associated with light levels ($F_{1,112.5}$ = 2.50; P = .117). The same was true for all other independent variables measured.

Open beds had significantly higher average light levels than older incubators ($F_{1,192.0} = 32.41$; $P < .001$) and Giraffe incubators ($F_{1,150.5} = 35.95$; $P < .001$; see Fig 4). Light levels depended on the method of respiratory support and bed type ($F_{6,188.9} = 4.05$; $P = .001$). Newborns in open beds on ventilators were exposed to higher light levels than newborns on nasal cannula/hood or room air with newborns on CPAP intermediate. The differences in light levels associated with the method of respiratory support were not significant for newborns in incubators.

Differences in light levels as a function of respiratory support were more apparent in open cribs/warmers than in incubators (ie, the bed type by respiratory support interactions were significant) throughout the range of light levels measured (90th through the 10th percentiles). The magnitudes of those differences decreased with decreasing light levels.

The variability in light levels over time was measured by the SD of the light levels across successive 6-second intervals (see Fig 5). The results were similar to those for light levels reported earlier. Variability was greatest in the open beds for newborns on ventilators (ie, there was a significant bed type by respiratory support interaction because of the greater variability in light levels for newborns in open cribs/warmers on ventilators; $F_{6,184.1}$ = 3.24; P = .005).

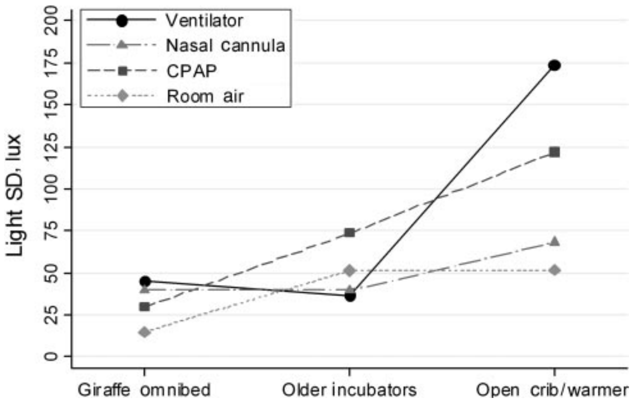

FIGURE 5
Expected SDs of light measurements (within each recording) according to bed type and respiratory support predicted by a GLMM, including PMA, bed type, and respiratory support and their interaction as predictors.

Excluding phototherapy, light levels rarely exceeded the AAP recommendations for all bed type/method of respiratory support combinations. Newborns that were ventilated in open beds exceeded recommendations most frequently (a median of 1.99% of the time [range: 0.00%–19.08%]).

The mean light level for the typical ELBW survivor during their time in the NICU (26–42 weeks' PMA) was 70.56 lux, the darkest 10th percentile of light levels was 21.19 lux, the brightest 10th percentile was 138.10 lux, and the percentage of time exceeding the AAP-recommended light level was 0.63%.

DISCUSSION

Sound and light levels increased significantly with age of the ELBW newborns during their stay in the NICU. The type of bed and respiratory support that covaried with age of the newborn explained those increases. Young, sick newborns were often initially in a Giraffe Omnibed incubator, the newest and technically most advanced of the incubators used in the study NICU. Giraffe incubators generated less internal noise than older incubators and effectively attenuated loud external room noises. When newborns reached 1500 g, servo control of temperature in the Giraffe incubators was withdrawn. Newborns that tolerated this challenge were transferred to older, noisier incubators, and eventually to open beds given case specific clinical considerations and bed availability. Byers et al[5] also identified the importance of bed type and respiratory support in a cross-sectional sample and a simulated study.

After accounting for bed type and respiratory support, none of the other variables we measured, including age of the newborn, significantly affected measured noise or light levels, with 1 exception. Newborns with ROP experienced higher noise but not light levels regardless of their bed type or respiratory support. Their clinical condition may have necessitated more interactions (eg, more frequent nursing care or more visits from the ophthalmologist), resulting in higher noise levels.

Younger, sicker newborns required more respiratory support than older, healthier newborns. Most study newborns required mechanical ventilation shortly after birth. As newborn pulmonary function matured and their medical condition improved, CPAP often replaced mechanical ventilation, followed by a hood or nasal cannula with additional improvement, and eventually room air before discharge. These age-related changes in respiratory support suggest a reduction, not an increase, in noise levels with age.

The interaction between respiratory support and bed type explains the apparent discrepancy in expected and recorded age-related noise levels. Noise generated by mechanical ventilation and CPAP instrumentation was attenuated by incubators. Shortly after birth, most ELBW newborns were placed in relatively quiet Giraffe incubators that helped buffer them from external noise. With age, the newborns were transferred to older incubators that also buffered them from external noises but generated significantly more internal noise than the Giraffe incubators. Finally, they were transferred to open beds fully exposing them to the physical environment of the NICU.

It is less obvious why light levels varied by type of respiratory support. At high light levels (the top 10th percentile), the highest and most variable light levels were recorded from newborns in open beds on ventilators, followed by newborns on CPAP, nasal cannula/hood, and finally, room air. One explanation is that the sicker newborns required closer evaluation and care involving increased lighting. That does not entirely explain why the respiratory support effect was reduced (and nonsignificant) for newborns in incubators. It is likely the explanation is more complex than can be explained by bed type and respiratory support alone.

When it was noisiest, the differences in noise levels as a function of bed type and respiratory support were much reduced compared with the quietest times. At the noisiest times, hospital staff and parental activities may have overwhelmed the contributions of bed type and respiratory support to the recorded noise levels. In contrast, light levels varied most by bed type and respiratory support when they were brightest, perhaps because newborns were shielded from bright external lighting in covered incubators but not in open beds.

Newborns in open beds on room air or nasal cannula/hood were susceptible to the widest variations in noise levels. Newborns in open beds on ventilators or CPAP experienced the widest variations in light levels. A combination of elevated internally generated incubator noise coupled with incubator buffering of externally generated room noises may explain the reduced noise variability in incubators. Covering incubators may be responsible for reduced variability in light levels. Variability in noise and light levels may be more disruptive to newborns than relatively constant noise and light levels.

It is unlikely that any NICU newborns consistently experience AAP-recommended noise levels.[17,18] Light levels in NICUs are much more likely to be within recommendations[4]; however, the importance of light/dark cycling and avoidance of intense exposures such as during phototherapy continue to warrant attention.[2]

Although level III NICUs in Western countries are similar in structural design and medical practice, each is a unique environment and must be evaluated individually. Appropriate noise and lighting management approaches must be individually tailored. Efforts to reduce noise and light exposures to vulnerable newborns in the NICU can best be met by a comprehensive approach to the physical environment. NICUs should be constructed to minimize excessive noise and lighting. With the proliferation of intensive care devices, reducing noise and light generated by those devices needs to be incorporated in their design. The significant differences in noise levels between recently manufactured incubators and older incubators in this and Byers et al[5] study indicate that incubator manufacturers have responded to concerns about noise levels in the NICU. Incubators can be designed to provide a physical environment conducive to growth and development without sacrificing caregivers' needs for communication and adequate lighting. For some applications (eg, transport, MRI scans, phototherapy, etc) individual ear and eye protection are particularly appropriate noise and light reduction approaches. Staff activities and visitation also need to be conducted with noise and light management in mind.

As we begin to better understand NICU environments and how to manage them, it is necessary to characterize sound and light levels that adversely affect newborns. Research indicating how NICU newborns of different ages and medical conditions respond to sound and light is needed to make appropriate recommendations concerning physical environments that promote optimal recuperation, growth, and development. Cycled light in NICUs was demonstrated to have positive clinical consequences.[2,20] Randomized, controlled trials demonstrating the clinical efficacy of noise reduction have not been conducted and are needed. The reported benefits of developmental care interventions may be due, in part, to alterations in the physical environment.[21] Understanding the components of comprehensive interventions that are efficacious is critical to improving care.

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