AMERICAN ACADEMY OF PEDIATRICS

Committee on Environmental Health

Noise: A Hazard for the Fetus and Newborn

ABSTRACT. Noise is ubiquitous in our environment. High intensities of noise have been associated with numerous health effects in adults, including noise-induced hearing loss and high blood pressure. The intent of this statement is to provide pediatricians and others with information on the potential health effects of noise on the fetus and newborn. The information presented here supports a number of recommendations for both pediatric practice and government policy.

ABBREVIATIONS. dB, decibels; dBA, A-weight; DNL, day-night average sound level; ICD-9, *International Classification of Diseases, Ninth Revision*; dBALeq24, personal equivalent 24-hour noise exposure; NICU, neonatal intensive care unit; IEC, individualized environmental care; EEG, electroencephalogram.

BACKGROUND

Noise is undesirable sound. *Sound* is vibration in a medium, usually air. Sound has intensity (loudness), frequency (pitch), periodicity, and duration. The loudness of sound is measured in decibels (dB), a logarithmic scale. The ability to hear sounds at certain frequencies is more readily lost in response to noise; therefore, the intensity is adjusted for frequency to give the A-weight (dBA). Most of our knowledge about the damage to people from noise is from studies of persons with occupational exposures. The standard for the workplace is no more than 8 hours of exposure to 90 dBA, 4 hours to 95 dBA, 2 hours to 100 dBA, with no exposure allowed to continuous noise above 115 dBA or impulse noise above 140 dBA. In nonoccupational settings, environmental noise is expressed as a day-night average sound level (DNL). For the protection of the public health, the US Environmental Protection Agency has proposed a DNL of 55 dB during waking hours and 45 dB during sleeping hours in neighborhoods, and 45 dB in daytime and 35 dB at night in hospitals.[1]

Exposure of adults to excessive noise results in: (1) noise-induced hearing loss that shows a clear dose-response relationship between its incidence and the intensity of exposure and (2) noise-induced stimulation of the autonomic nervous system, which reportedly results in high blood pressure and cardiovascular disease (reviewed by Kam et al[2]).

Noise may damage fetuses and newborns. Many pregnant women are exposed to noise in the workplace.[3,4] This statement reviews the evidence collected since 1974 that fetuses and newborns exposed to excessive noise may suffer noise-induced hearing loss and other health effects.

The recommendations in this statement do not indicate an exclusive course of treatment or serve as a standard of medical care. Variations, taking into account individual circumstances, may be appropriate.

THE FETUS

Development of Hearing

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, and are consistently present after 28 weeks, indicating maturation of the auditory pathways of the central nervous system.[6] The hearing threshold (the intensity at which one perceives sound) at 27 to 29 weeks of gestation is approximately 40 dB and decreases to a nearly adult level of 13.5 dB by 42 weeks of gestation, indicating continuing postnatal maturation of these pathways.[7] Thus, exposure of the fetus and newborn to noise occurs during the normal development and maturation of the sense of hearing. Sound is well transmitted into the uterine environment.[8,9] One to 4 seconds of 100 to 130 dB of 1220- to 15 000-Hz sound is used as a stimulus to document the well-being of the fetus.[10,11]

Potential Fetal Effects

In one study,[12] children with high-frequency hearing loss tested at 4 to 10 years of age were more likely to have been born to women who were exposed consistently to occupational noise in the range of 85 to 95 dB during pregnancy. However, one of the several weaknesses in this study was retrospective noise evaluations. Studies using animals have demonstrated an increased sensitivity of the developing cochlea to noise-induced damage,[13,14] but this effect has not been confirmed in humans.

A Chinese study found that self-reported exposure to noise during the first trimester of pregnancy was associated with the congenital anomalies listed in the *International Classification of Diseases, Ninth Revision* (ICD-9) classifications of chromosomal anomalies and other categories (ICD-9 758 and 759) (ratio of observed to expected, 2.3; $P < .05$).[15] A slight increase in reports on birth certificates of observable birth defects (excluding polydactyly) was noted in one study of black women exposed to airport noise (dB >90; $P < .02$),[16] but no such risk was found in a more well-designed second study.[17] In addition, no increased risk of malformation was found in offspring of women occupationally exposed to 80 dB during an 8-hour shift.[18] Teratogenic effects have been described in animals prenatally exposed to noise.[19,20]

Rhesus monkeys that had been exposed to noise in utero had persistently higher levels of cortisol and corticotropin than did unexposed animals,[21] as well as more abnormal social behavior.[22] In rats, prenatal noise exposure also increased serum corticosterone levels and produced abnormal behavior.[23] In humans, maternal placental lactogen was significantly lower after 36 weeks of gestation in women subjected to airport noise than women living in quiet areas.[24] In other studies, no consistent hormonal or blood flow changes were found in experimentally exposed humans.[25,26]

An increased risk of shortened gestation has been shown in four studies. Women exposed to 80 dB for an 8-hour shift were at increased risk of preterm delivery (relative risk, 1.6; 95% confidence interval, 0.9 to 2.9).[27] In a study involving 22 761 live births, women with self-reported noise exposure in health care jobs had a slight increase in risk of preterm delivery (ratio of observed to expected, 1.5; $P < .05$).[28] Results in a third study showed the length of gestation in female infants to be inversely correlated to maternal residential noise exposure from an airport ($r = -0.49$; $P = .0008$).[29] In a case-control study of premature births among US nurses, self-reported loud, constant noise was significantly associated with gestations of <37 weeks ($P < .005$).[30] Four other studies have examined this issue; results of two studies showed no increase in preterm birth between noise-exposed and unexposed women. Two other studies were inconclusive.[15,31–33]

Decreased birth weight has also been associated with noise exposure. In a retrospective Danish study, the birth weights of infants born in the hospital to women aged 20 to 34 years were significantly less (69 g, $P = .03$) if the mother resided in an area where the DNL of aircraft noise exceeded 60 to 65 dB.[34] Socioeconomic status was controlled by assessing health insurance, and smoking status was not determined. After adjusting for family income and infant gender, the proportion of birth weights <3000 g was significantly higher in the high noise group (23.8% vs 18.1%, $P = .02$). In a separate study, no effect of air traffic noise on birth weight was found[29] when noise was analyzed as a continuous variable. When categorical analysis was used, however, birth weights of female infants in the high noise group (>99 dBA) were significantly less than those in the combined low and moderate noise exposure group.[35] Increases in the relative rates of newborns with a birth weight of <3000 g was associated with increasing maternal noise exposure from increases in the number of jets using a nearby airport.[36] In addition, a prospective study of 200 women showed no association of noise >85 dBALeq24 (personal equivalent 24-hour noise exposure) and decreased birth weight.[37] This study also found no association between smoking and birth weight. Reduced fetal weights have been observed in some studies using animals,[19,38] but not in others.[39] In summary, there have been few well-controlled randomized studies investigating the relationship between noise and fetal hearing loss, prematurity and decreased birth weight. However, several of these studies suggest that noise may be associated with these outcomes. It is possible that noise could be a marker for other risk factors.

THE NEWBORN

Noise-induced Hearing Loss

Numerous studies have documented the continuous noise exposure of infants, without intervening periods of quiet, associated with neonatal intensive care units (NICUs)[40–43] (see Table). Noise levels and their effects generated by the new modalities of respiratory therapy (eg, high-frequency oscillatory ventilation and high-frequency jet ventilation) or by extracorporeal membrane oxygenation have not been reported.

Many studies have documented hearing loss in children cared for in the NICU (NICU graduates).[45,46] Three such studies (since the 1974 statement by the American Academy of Pediatrics' Committee on Environmental Health[5]) that investigated the synergism of aminoglycosides and noise exposure had conflicting results.[47–49] In one, all five cases of moderate-to-severe sensorineural hearing loss were in infants treated with kanamycin and kept in incubators, suggesting a synergistic response.[47] In addition, 52% of 56 incubator-treated children with normal

TABLE. Noise levels

Quality	Peak Intensity, dBA	Example[2]	Inside Incubator[41]	Effect
Just audible	10	Heartbeat		
Very quiet	20–30	Whisper		<35 dBA desired for sleep
Quiet	40	Average home		
	50	Light traffic	Background	<50 dBA desired for work
Moderately loud	60	Normal conversation	Motor on and off	
	70	Vacuum cleaner	Bubbling in ventilator tubing	Annoyance
Loud	80	Heavy traffic Telephone ringing	Tapping incubator with fingers	
	90	Pneumatic drill	Closing the metal cabinet doors under the incubator	Hearing loss with persistent exposure
Very loud	100	Power mower	Closing solid plastic porthole	
Uncomfortably loud	120	Boom box in car[44]	Dropping the head of the mattress	Pain and distress
	140	Jet plane 30 m overhead		

hearing had minor changes on their audiograms suggesting minor noise-induced cochlear lesions.[48] D'Souza et al[49] studied 26 survivors of severe perinatal asphyxia, who were kept in incubators and 15 of 26 received gentamicin. Only one child had sensorineural deafness. Anagnostakis et al[46] assessed hearing at 6.5 years of age in 98 preterm NICU graduates. Nine had sensorineural hearing loss that was significantly associated with apneic spells, hyperbilirubinemia, and hypothermia and not associated with duration of incubator care or exposure to aminoglycosides or conventional ventilation.

Other Effects

Long et al[50] demonstrated that hypoxemia occurred in infants in conjunction with sudden loud noise (of approximately 80 dB). One study found that loud noises in the NICU significantly changed the behavioral and physiological responses of infants.[51] Chick hatchlings reared in an NICU-like environment with similar noise levels failed to demonstrate habituation in their peeping behavior after a white noise stimulus.[52]

Three studies have examined the effects of noise reduction. In one, earmuffs were worn by premature infants, and the effect on sleep time was examined. Substantial increases in quiet sleep time occurred while the infants wore the earmuffs.[53] Further research is required to determine the effect of the sensorineural deprivation. In the second study, individualized environmental care (IEC) to low birth weight infants included reduction in the noise caused by NICU activities and less opening and closing of the incubator. The group treated with environmental interventions needed significantly fewer days of respiratory support on a ventilator and required fewer days of oxygen administration.[54] In a further study of IEC that incorporated prolonged periods of quiet, significant quantitative differences in regional electroencephalograms (EEGs) obtained at 2 weeks after the (maternal) expected date of confinement were found between low-risk premature infants randomized to the IEC or to the standard care protocols.[55] The EEGs of IEC infants were not significantly different from those of full-term infants in the control group, suggesting that the neurologic development of infants in the IEC group more closely resembles the development that occurs in utero.

Several studies have investigated noise reduction techniques (for a review of noise reduction techniques, see Kam et al[2]). In one study,[56] covering the infant incubator significantly reduced the level of noise within an incubator. In addition, asking staff to modify their behavior resulted in a lowering of baseline noise levels.[50] A survey of hospital employees indicated their perception that noise levels were high enough to interfere with their work and with the comfort and recovery of adult patients.[57]

CONCLUSION

Results of these studies suggest that: (1) exposure to excessive noise during pregnancy may result in high-frequency hearing loss in newborns, and may be associated with prematurity and intrauterine growth retardation, (2) exposure to noise in the NICU may result in cochlear damage, and (3) exposure to noise and other environmental factors in the NICU may disrupt the normal growth and development of premature infants. On the basis of these study results, noise-induced health effects on fetuses and newborns merit further study as clinical and public health concerns.

RECOMMENDATIONS

1. Pediatricians should encourage research to determine health effects of noise exposure on pregnant women and their fetuses and infants.
2. Pediatricians are encouraged to consider screening for noise-induced hearing loss those infants who were exposed to excessive noise in the uterus or as a newborn. Occupational sources of such noise include jobs in which women are required to wear protective hearing devices. Environmental sources of such noise include rock concerts, boom boxes in cars, and airport jet traffic.
3. Pediatricians are encouraged to monitor sound in the NICU, and within incubators. A noise level >45 dB is of concern. Ideally, as proposed by the US Environmental Protection Agency, a noise level exceeding 45 dB is best avoided. NICU personnel should devise simple strategies to reduce noise in the nursery (no tapping or writing on the tops of incubators and hoods, careful closing of incubator doors, soft shoes). If such simple, inexpensive strategies fail to reduce monitored noise levels, more technical strategies need to be considered (incubator covers, use of less noisy equipment). When purchasing new equipment or renovating facilities, sound control should be considered.
4. Pediatricians should encourage manufacturers to reduce noise from medical equipment.
5. The National Institute of Occupational Safety and Health should consider further research on noise exposure during pregnancy.
6. The Occupational Safety and Health Administration should consider pregnancy in setting their occupational noise standards.

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